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A FORECASTING MODEL OF MANPOWER REQUIREMENTS IN THE HEALTH OCCUPATIONS.

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DESCRIPTORS- *ECONOMICS, *EMPLOYMENT PROJECTIONS, *HEALTH SERVICES, *HEALTH OCCUPATIONS, *HEALTH EDUCATION, *RESEARCH, MANPOWER NEEDS, MANPOWER UTILIZATION, PREDICTION, PARAMEDICAL OCCUPATIONS, RESEARCH OPPORTUNITIES, RESEARCH METHODOLOGY,

REPORTED IS THE DEVELOPMENT OF A MODEL, OR CONCEPTUAL FRAMEWORK, TO BE USED IN THE ANALYSIS OF THE NATURE OF THE SUPPLY AND DEMAND FOR HEALTH MANPOWER. THE MODEL IS DESIGNED TO PREDICT, UNDER CERTAIN ASSUMPTIONS, THE DEMAND, SUPPLY, EXCESS DEMAND, AND EMPLOYMENT OF HEALTH PERSONNEL FOR SOME PERIOD IN THE FUTURE. THE MANPOWER REQUIREMENT FORECASTS OF THE MODEL ARE BASED ON THE ECONOMIST'S CONCEPT OF DEMAND, RATHER THAN ON THE "NEED" CONCEPT WHICH HAS BEEN COMMONLY USED IN MAKING FORECASTS IN THE PAST. THE MODEL AS PRESENTLY DEVELOPED IS RECURSIVE IN DESIGN AND IS APPLICABLE FOR FORECASTS OF FIVE TO 15 YEARS INTO THE FUTURE. THE DOCUMENT PRESENTS (1) THE DEVELOPMENT OF THE MODEL, (2) INFORMATION ON THE DEMAND FOR HEALTH SERVICES, (3) A DISCUSSION OF THE COEFFICIENTS AND THE CONSTRAINTS USED IN THE OPERATION OF THE MODEL, (4) THE TESTING OF THE MODEL INCLUDING THE FORECASTS MADE ON EMPLOYMENT FOR 20 SELECTED HEALTH OCCUPATIONS FOR THE YEAR 1960 (KNOWN DATA AVAILABLE), AND (5) THE EVALUATION AND COMPARISON OF THE ESTIMATES OF THE MODEL TO THE KNOWN DATA. THE USEFULNESS OF THE MODEL AS A POLICY TOOL AND ITS IMPLICATIONS FOR RESEARCH IN OTHER FIELDS AS WELL AS IN HEALTH OCCUPATIONS ARE INDICATED. (DS)

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CHAPTER I: INTRODUCTION

Interest in the study of the economics of health is a comparatively recent phenomenon. Economists in the past have devoted considerable energy and resources to the study of manufacturing and transportation in particular, generally giving little attention to the service sector. The study of the banking system is a notable exception to this last generalization. Yet there are several reasons why the economist should be interested in the study of health. Geographically, the health industry represents a very ubiquitous type of activity. This industry in 1962 was approaching a $30 billion-a-year operation (74, p.6). Thus the study of the health industry is the study of an important sector of the economy.

The health industry has several characteristics which make it at the same time more interesting but also more difficult to study than manufacturing, for example. The traditional goal imputed to the entrepreneur in the theory of the firm is the maximization of profit. This assumption is singularly inappropriate in the case of the health industry. It is further difficult to hypothesize what a reasonable objective function for the health industry would be. The problem of external effects is more prevalent in the production of health services than in most types of economic activity. The social benefits of providing health services are much greater than the private benefits, notably in the treatment of infectious diseases. Some health services, notably some of the environmental health services, can be classified in the category of public goods. One person's enjoyment of the benefits of air pollution control does not subtract from another person's enjoyment of these same benefits. All of these

externalities render the usual optimal solutions to competitive models nonoptimal. Stated another way, no possible price system in a competitive system will lead to a welfare maximum, assuming this can be defined.

The policy implications of research findings regarding the health industry are more easily put into practice than would be the case in research on manufacturing or trade, for example. This is because much of the decision making in the allocation of resources to health services is done by administrative agencies, not by private individuals. The actions of these agencies can be much more readily influenced by research findings than would be true of private individual decision makers, due to the smaller number of decision making units involved.

These are reasons why economists in general should be interested in exploring the economics of health. There are even more compelling reasons why manpower economists in particular should be interested in studying the health industry. Compared to other industries, the health industry is relatively labor intensive (74, p.6). Employees in the health field include physicians, who are among the highest paid and most highly skilled workers in the labor force, as well as hospital ward maids, who are among the lowest paid. Almost all intermediate skill levels are also represented. Further, if one is to believe much of the literature on the subject, labor market imbalances among many of the occupations represented are very serious. Acute shortages of physicians, dentists, professional nurses, and many other skilled occupations are said to exist (54, p.8) and are expected to persist and perhaps become even more serious in the future unless rates of training or other variables are altered. It is to this aspect of the economics of health that this study is devoted.

Specifically, the purpose of this analysis is to develop a model, or conceptual framework, within which to analyze the nature of the supply of and demand for health manpower. The model is designed to predict, under certain assumptions, the demand, supply, excess demand, and employment of health personnel for some period in the future. As presently developed, the model is applicable for forecasts of five to fifteen years into the future. Simpler models may be more efficient for forecasting periods of less than five years, and while the model presented herein can be used for forecasts of magnitudes more than fifteen years into the future, some modification of the means used to estimate parameters is desirable. This is discussed further in the last chapter of this study.

Requirements Versus Need

It is necessary at the outset to define rigorously what I mean by manpower "requirements." Most previous studies have in one sense or another concentrated on something more properly designated as the "need" for manpower in certain occupations (77, pp.183-191). Most of these studies, including the above source and the Health Manpower Source book (109, pp.41, 60), select some employment to population ratio as a standard and then forecast "need" based upon this norm. We have, for example, an estimate of "number of dentists required in 1975 to raise below-average states to the 1958 average national dentist population ratio" (109, p.60), and "number of physicians required in 1960 to maintain the 1949 physician-population ratio" (77, p.185). I am not talking about "requirements" in this sense, for a very simple reason. If we wish to forecast requirements based up "need," we must first make several value judgments to determine "need." To be even reasonably objective about this

determination, it becomes necessary to define some "index of health," and to determine the change in this index caused by the addition of one physician or one nurse and so forth to the active labor force. A value judgment is still required to select an acceptable or optimal "index of health." Although some research has been done on an index of this type, knowledge has not progressed to the point where such an index can be used as the basis for forecasting manpower "needs." Thus any forecast of manpower needs made at this point is dependent entirely upon an arbitrary value judgment.

I propose to be more objective and pragmatic than this. I define manpower "requirements" for occupation as <u>the number of persons who would be employed at given wage rates if there were no shortage of available trained personnel, given the amount of resources available to pay them</u>. This is identical with the economists' concept of demand. I claim this concept is superior to the "need" concept for at least two reasons: (1) Demand is at least conceptually measurable without recourse to any value judgment by the analyst. While it is no cardinal sin for the analyst to make value judgments as long as they are explicitly stated, his results will be more acceptable to policy makers the smaller the number of value judgments upon which these results are based. (2) Any forecast of manpower requirements based upon the concept of "need" ignores the fundamental economic tenet of scarce resources. If we were to expand the supply of nurses to meet "need" by increasing the output of training institutions, we still would not have assured that the health industry will have sufficient resources available to hire all of the personnel trained.

An Index of Health

The above statements are not intended to imply that research on "needs" is not important. It is simply a different problem than the one which I wish to consider.

In order to be useful, any index of health must be capable of handling empirical data. For this reason, most indices developed to date are expressed as mathematical models. An index of health must consider information other than mortality data, even if this is broken down by age, sex, cause of death, or other relevant factors. Morbidity information is also pertinent. There is, however, a measurement problem. This requires the specification of some type of social welfare function, either explicitly or implicitly. Using one welfare function, we can measure losses due to death or ill health in terms of gross national product foregone. This would imply that there is no social cost involved when a retired individual becomes ill, and maximization of social welfare would dictate devoting no resources to the care of such individuals. On the other hand, if we allow noneconomic variables to enter into the objective function, then the aforementioned measurement problem becomes important. How does one measure the cost of "suffering"?

Because of these conceptual problems (103), several simple indices of health have been proposed as proxies for some more refined index. Swaroop and Uemura (90) have proposed that deaths at age 50 and above as a percentage of all deaths is a useful measure where data on vital statistics are very scarce. In countries such as the United States, where more detailed data from national health surveys is available, more complex and theoretically more correct indices are obtainable. Perhaps the most advanced model

proposed to date was introduced by Chiang (118). His index of health, denoted H, is equal to $1/P \ \Sigma_x \ P_x \ [1 - (\bar{N}_x \ \bar{T}^*_x + 1/2 \ m_x)]$. P is the size of the total population, while P_x is the number of persons in age and sex category x. $\bar{N}_x$ is the observed average number of illnesses per person per unit of time and $\bar{T}^*_x$ is the average duration of illness in the same time period. Both $\bar{N}_x$ and $\bar{T}^*_x$ can be derived from sample data. The age-specific death rate, m_x, is the proportion of persons in age and sex category x who die during the time period in question (103, pp.10, 11). Chiang then treats H as a random variable taking on values in the interval $0 \leq H \leq 1$, and computes the moments to get estimates of the mean and variance of H. Because H is affected by the age and sex distribution of the population in question, it is not useful for comparing two populations having dissimilar age and sex distributions. Chiang introduces an "age-adjusted index of health" which can be used to compare the state of health in different nations, states, or points in time.

This index still does not tell us the optimal amount to spend on health or the "minimum acceptable" level of the index. Much work remains to be done on this aspect of health economics.

Projections Versus Forecasts

There appears to be a lack of agreement regarding the difference between a forecast and a projection. Mangum and Nemore (62) make the following differentiation.

> "It is common practice to differentiate between projections and forecasts, but in reality the difference is in the confidence of the forecaster. The projector, after examining past trends and current developments, develops implicitly or explicitly, a working model of the system. He sets forth a series of assumptions about how the important variables are likely to behave in the future,

and then uses these assumptions to modify extensions of the past performance of the variables. The projector stands behind his product only to the extent that his assumptions may be expected to prove valid, and the accuracy of his projections depends on both the realism of the assumptions and the identification of all the relevant variables. The forecaster is a projector who has the confidence and the institutional freedom to state his conclusions unconditionally and to stake his reputation on them" (62, p.2).

This is not the sense in which I wish to use these terms. I define a projection as the estimation of the magnitude of some variable at a future point in time, using as explanatory variables only current and past magnitudes of the same variable. If x is the variable to be estimated and we are currently in time t, then by my definition a projection of x in time t+n must be of the form $x_{t+n} = f(x_t, x_{t-1}, \ldots, x_{t-s})$. Projection is trend extapolation, not necessarily linear. I define a forecast as the estimation of the magnitude of some variable at a future point in time, using as explanatory variables any other variables which may be considered to be relevant. Current, past, or forecast future values of these explanatory variables may be used. If x is the variable to be estimated and we are currently in time t, then a forecast of x in time t+n is of the general form $x_{t+n} = g(x_t, x_{t-1}, \ldots, x_{t-s}, 0_{t-r}, \ldots, 0_t, \bar{0}_{t+1}, \ldots, \bar{0}_{t+m})$. The 0_t denote "other variables," and the bar denotes forecast values. It may be noted that by my definition all projections are forecasts, but the reverse is not true.

The reason for making this distinction is that I feel projection techniques are of very limited usefulness. They do provide estimates of magnitudes for future periods, and may even be more accurate than more sophisticated techniques for short-range forecasts. However, projection models provide almost no information regarding <u>why</u> certain changes in

variables would be expected. It is simply assumed that all factors which affect the variable being projected will continue to change in the same manner in the future as they have in the past. The number of assumptions needed for a projection model is smaller than for some other type of forecasting model, but they are correspondingly more heroic. For these reasons the model developed herein is explicitly designed to operate on principles other than projection techniques. In the empirical analysis of Chapter 7, projection techniques are utilized for the estimation of many parameters. Two comments are in order here: (1) It is by no means necessary that the model be utilized in this manner. In its full generality the model can accommodate numerous different techniques for the estimation of parameters. (2) Even though projection techniques are used, they are not used to estimate employment or manpower requirements directly. This makes the model much richer in potential information than a straightforward projection model.

CHAPTER II: PRESENTATION OF OVERALL MODEL

The purpose of this chapter is to present a generalized, overall view of the model used to generate a forecast of manpower requirements and employment in the health industry. Two models are used. The first, referred to as the "recursive programming model," is of primary interest. The second, referred to as the "naive model," is presented only to provide a standard of comparison for evaluating the forecast generated by the recursive program.

The recursive programming model is formulated as follows.

Minimize: $\Sigma_j [r_j (x^*_{jT} - x_{jt}) / x^*_{jT}]^2$

Subject to:

$x_{jt} \leq (1 + B_{j,max,t})\, x_{j,t-1}$	$j = 1, 2, \ldots, n$
$x_{jt} \geq (1 - B_{j,min,t})\, x_{j,t-1}$	$j = 1, 2, \ldots, v$
$x_{jt} \geq 0$	$j = v+1, v+2, \ldots, n$
$\Sigma_j AAE_{jt}\, x_{jt} \leq TR_t$	$j = 1, 2, \ldots, n$

The following matrix equations are also used. $X^*_t = X_t + Y_t$ and $A^*_t M_t = X^*_t$. The naive model is simply of the form $X_t = A_t M_t$, again written in matrix notation. The symbols are defined as follows.

j = an index number denoting occupations.

n = the limit to j, i.e. we are considering n occupations.

k = an index number denoting categories of health services.

s = the limit to k, i.e. we are considering s categories of health services.

t = an index number denoting time, which is assumed discrete.

T = the time horizon, i.e. the time period for which the forecast is prepared.

B = the base period, i.e. the time period as of which the forecast is prepared.

r_j = a weight representing the "relative urgency" of reducing excess demand as a percentage of total demand for occupation j.

x^*_{jt} = total "ceteris paribus" demand for personnel in occupation j in time period t.

x_{jt} = employment in occupation j in time period t.

$B_{j,max,t}$ = the maximum percentage increase possible in the number of workers in occupation j during time period t.

$B_{j,min,t}$ = the maximum percentage decrease possible in the number of workers in occupation j during time period t.

v = a number such that $0 \leq v \geq n$ which shows the number of occupations for which a lower bound to supply is appropriate.

AAE_{jt} = average annual earnings in occupation j during time period t.

TR_t = total resources available to the health industry to be disbursed as earnings to personnel in the n occupations considered in time period t.

A^*_t = a matrix with elements a^*_{jkt}. These elements are referred to as "demand coefficients" and represent the number of personnel in occupation j that the health industry would desire to employ per unit level of demand for health services of type k in time period t, assuming that employment in other occupations is at specified levels.

A_t = a matrix with elements a_{jkt}. These elements are referred to as "technical coefficients" and represent the number of personnel in occupation j that the health industry actually employs per

unit level of demand for health services of type k in time period t.

M_t = a vector with elements m_{kt}. These elements represent the demand for health services of type k in time period t. The units in which the elements are expressed may vary within the vector, but are all expressed in some physical units, e.g. visits, patient-hours, admissions, persons, and so forth.

Y_t = a matrix with elements y_{jkt}. These elements represent excess demand for personnel in occupation j to provide health services of type k in time period t.

For t = B+1, B+2, ..., T, it is understood that values of all variables are forecast values, unless specifically noted otherwise.

This model is based upon a recursive programming model developed by Richard H. Day for another purpose (36). The model used in this study differs from Day's in several important respects. Day uses a linear objective function (36, p. 23), while the model presented herein uses a quadratic objective function. This makes Day's concept of the equated constraint matrix useless for our purposes, since a quadratic program may have "interior solutions" (52, p. 11). Day also expresses his solutions in terms of explicit first order difference equations. This is not possible in the model utilized herein, because it utilizes variable coefficients. Further, these variable coefficients are not amenable to statement as explicit functions of time. This is true in particular of the $B_{j,max,t}$.

The following four chapters are devoted to analyzing specific portions of the model. Since the demand for labor is a derived demand, it is necessary to study the demand for health services. Further, since the

personnel requirements of such environmental health services as sanitation differ greatly from the personnel requirements of mental hospitals, for example, it is useful to decompose the demand for health services into some number of sub-components. The determination of this decomposition as well as the determination of the independent variables useful in forecasting the demand for health services is the topic of the following chapter.

If we have a forecast of M_T, the next step is to determine $A_T M_T$ in the case of the naive model or $A_T^* M_T$ in the case of the recursive program. In general, A_T and A_T^* are functions of A_B and A_B^* respectively and of certain exogenous variables. The forecasting of these technical and demand coefficients is discussed in Chapter 4. Note that forecasts could be generated by assuming the coefficients constant over time. Empirical evidence and common sense tend to indicate that such forecasts would be of limited usefulness, at least for forecast periods greater than two or three years.

In using the recursive programming model, once we have determined a vector $X_T^* = A_T^* M_T$, we have still only considered the demand side of the market. In fact, we have only considered what I term "ceteris paribus" demand. That is, we have considered the demand for personnel in each occupation, assuming that employment in other occupations is at certain levels. We must introduce the total resource constraint, which essentially may make it impossible to attain the ceteris paribus level of demand for all occupations simultaneously. Supply considerations are discussed in Chapter 5 and the total resource constraint in Chapter 6.

The objective function used herein is assumed to be the objective of the health industry and not of society as a whole, to the extent that these differ. The solution to the constrained optimization problem therefore

represents manpower requirements as modified by supply restrictions and has nothing to do with the concept of "need." This solution represents actual employment as well as "effective demand," given the forecast supply conditions and taking into account simultaneous interactions between occupation groups. In an imperfect manner, substitutability between occupations is thus considered. The reasons for the form of the objective function and a discussion of the weights for this function are contained in Chapter 6.

The recursive programming model may be tested by comparing the results of a forecast generated by using it against actual employment in the year T, at such time as these data become available. A test of this nature is undertaken in Chapters 7 and 8. This tests the accuracy of the forecast of X_T. Conceptually we could test the accuracy of the forecast of X_T^* by gathering data on Y_T, when they become available, and adding this to X_T. This is difficult data to obtain, and no direct test of the reliability of the forecast of X_T^* is undertaken herein. The primary value of this forecast lies in its role in the recursive system of quadratic programs. By examining the nature of the Lagrange multipliers, which are defined in Chapter 9, we can determine those occupations for which there exists a shortage of supply. This furnishes a basis for policy recommendations regarding the level of operation of training activities.

CHAPTER III: THE DEMAND FOR HEALTH SERVICES

In the specification of any forecasting model, there is always a question of the degree of disaggregation in the variables which are to be used. The "optimal degree of disaggregation" generally depends in the first instance upon the purposes for which the model is developed and the degree of accuracy desired of the forecast magnitudes. Unfortunately in most instances the constraint of limited research funds is binding, causing some compromise of the desired state of affairs to conform to the possible state. This compromise can be effected by making the variables of the model conform to available data or by accepting "poorer" estimates of the given variables than would be desired. In my opinion, it is preferable to have an estimate of the right variable which is based upon mediocre data rather than to have an excellent estimate of the wrong variable. In the analysis at hand, I am essentially ignoring data availability constraints in the first six chapters and am choosing my variables and the degree of disaggregation of these variables on other grounds. In the testing process, harsh reality causes some compromise of principles, but even here I am reluctant to modify the model to conform to available data. Instead I use the best estimates I can get of the variables I hypothesize to be relevant.

In this analysis, the number of classes of health services considered is wholly dependent upon the usefulness of the breakdown for the purpose of forecasting manpower requirements. I am not attempting to use the results of this study to influence policy on the number of hospitals constructed or other similar problems. As long as the elements of M_t are chosen in such a manner that the elements of A_t are defined and can be forecast for

some future period with a "high degree" of accuracy, this breakdown of services is allowable for my purposes. There is perhaps no a priori means of ascertaining the "optimal" breakdown of services. The "optimal" breakdown may be defined as that breakdown which leads to the estimates of manpower requirements which most closely approximate actual magnitudes. I hypothesize that the following categorization is useful for my purposes, and subsequent discussion is couched in terms of this framework. The method of approach is quite general, and the usefulness of this approach cannot be determined by its forecasting ability using any particular breakdown of the demand for health services. It is only the combination of method of approach and a given specification of variables which can be tested at any one time.

Table 3.1. Elements of M_t.

k	Description
1	Services of short-stay hospitals.
2	Services of nervous and mental hospitals.
3	Services of "other" hospitals.
4	Physicians' services outside hospitals.
5	Dental services.
6	Environmental health services.
7	"Other health" services.

The breakdown of hospitals into several categories is necessary for a model of the type developed herein, as manpower requirements vary greatly from one type of hospital to another (Table 4.3). Also it is all too easy to overemphasize the importance of short-stay hospitals, since this is the class of hospital most persons have the greatest contact with in the normal course of events. Yet "more than half of all hospital beds in this country

are occupied by the mentally ill" (72, p.4).

M_t is a function of several variables, the most important of which have historically been considered to be population in an age and sex category (N_{it}), per capita disposable income and its distribution (D_t), the price of services (P_{kt}), and various institutional variables (I_{1t}). These institutional variables include factors such the percentage of the population covered by various types of hospital and medical insurance, prepaid medical plans, and governmental programs such as medicare. We can thus write in vector-matrix notation $M_t = f(N_{it}, D_t, P_t, I_{1t})$. There is, of course, the danger that we may have ignored some important explanatory variables in this formulation, or that some different formulation would be more useful for purposes of prediction. For example, considerable work has been done recently in analyzing the incidence of illness by occupation. It is possible, but intuitively unlikely, that M_t is a more stable function of the occupational composition of the population than of its age and sex distribution. In any event, better data on current and future magnitudes of the latter variable exist, and the incidence of illness of occupation is not recommended as an independent variable in this analysis.

Empirical evidence tends to indicate that the demand for health services varies between geographical locations. Data from the recent national health survey (102, p.28) indicate that the number of discharges from short-stay hospitals per 1,000 population ranged from 117.5 in the Northeast to 135.8 in the South during the period July 1963-June 1965[1]. The number of physician visits per person in the period July 1963-June 1964 ranged from 4.2 in the South to 5.4 in the West (128, p.13). The same source gives

[1]Using the Bureau of the Census definition which divides the United States into four regions: Northeast, North central, South, and West.

some evidence to indicate that these differentials are fairly stable over a five-year period. The number of dental visits per person in the July 1963-June 1964 period ranged from 1.1 in the South to 2.1 in the Northeast.

These differences are often ascribed to "habit" or "custom" and are considered important in forecasting only to the extent that significant shifts in the percentage of population located in different areas are foreseen during the forecast period. If geographical shifts in population are expected, it is difficult to ascertain the extent to which this effect would in turn cause changes in the per capita demand for health services within a region. I consider it probable that empirical analysis will disclose that D_t or P_{kt} explain these geographical differences in rates of service utilization.

Similar arguments could be raised concerning the differences in the percentage of population in urban versus rural areas. Again differences in the utilization rates for various categories of medical services exist, as indicated in Table 3.2.

Table 3.2. Utilization Rates for Various Categories of Health Services, United States, July 1963-June 1964

Residence	Discharges From Short-stay Hospitals per 1,000 Persons[a]	Average Length of Stay	Physician Visits per Person	Dental Visits per Person
SMSA[b]	122.2	8.8	4.8	1.8
Outside SMSA				
Farm	111.7	6.8	3.3	0.9
Nonfarm	145.0	7.6	4.3	1.2

Source: Columns 1 and 2 (102, p.29), Column 3, (128, p.13), Column 4, (127, p.16).

[a]Data for July 1963-June 1965.

[b]Standard Metropolitan Statistical Area.

It is noted that the farm population has a lower level of per capita utilization of the three categories of health services listed than do other groups in the population. Further, since the farm population is declining as a percent of total population (92, p.143), it may appear that the urban-rural or farm-nonfarm population distribution should be an explanatory variable in forecasting the demand for health services. It is my hypothesis that this effect can be accounted for by the per capita income variable, i.e. it is income and not residence which is determining.

It is often suggested that the rate of utilization of health services is positively correlated with education levels (58, p.29). The argument is that better educated persons are more concerned about their health, as well as being more informed regarding the advantages of using health services. It might be expected a priori that better educated persons would make greater use of preventive services and regular checkups than the less educated, which in turn might lead to a lower utilization of curative services by the better educated. In fact it is conceivable that this effect could lead to a reduction in total health services used by better educated groups. Some evidence to support this hypothesis has been found (43, p.64). Again my argument is that the per capita income variable should be highly correlated with the education variable and in effect serves in part as a proxy for the latter. All of this is "armchair empiricism," and a good factor analysis study is needed to determine the importance of the education and farm-nonfarm variables. There are numerous other types of variables which could affect the demand for health services. The degree of activity of various nonprofit organizations such as the American Cancer Society in making the general public aware of the benefits of regular physical checkups could affect the demand for physicians' services, for example.

In this analysis, the four general categories of variables originally listed will be assumed to be sufficient to provide "good" forecasts of the demand for health services. For different categories of services, different variables will be important.

Population and Its Age and Sex Composition

Disregarding changes in the age and sex distributions of the population, increases in the size of the total population would be expected to cause a proportionate increase in the demand for certain types of health services, ceteris paribus. Examples are the demand for admission to short-stay hospitals, dental services, and physicans' office calls. There may be some effect of increased disease diffusion in a large population, or more mental disorders simply because of the increasing complexity of social relationships caused by a larger population, but these effects are probably of very minor significance and extremely difficult to estimate. In other types of health services, for example in the environmental health field, there is an element of the "community good" aspect present. It probably requires less than twice the facilities to provide sanitary sewage service to 2,000 persons as it does to 1,000 persons. For most categories of services, however, we may assume the demand increase is proportional to population increase, everything else being constant.

The difficulty arises in the fact that everything else is not constant. As population increases, the sex and particularly the age distributions also change. Further, the utilization of various categories of services varies greatly from one cohort group to another. Recent data from the national health survey (102, p.27) indicate that the number of discharges from short-stay hospitals for persons under 45 years of age was 115.2 per

1,000 population, with 6.4 days the average length of stay. For persons aged 45-64 the comparable figures were 147.9 discharges and 11.0 days average length of stay. For persons 65-74 years of age the figures were 181.3 discharges and 12.6 days average length of stay. At least for persons over age 45, the older cohort groups use hospital services more often and remain hospitalized for a longer period of time than younger cohort groups.

Another publication (116, p.16) gives data indicating that discharges from short-stay hospitals vary significantly by sex as well as age. The data in Table 3.3 indicate that hospitalizations per 1,000 persons are higher for females aged 15-44 than for males in the same age group. A large part of this difference is probably due to the fact that these are the child-bearing years. This suspicion is reinforced by noting that the average length of stay for females aged 15-24 years is only 4.6 days, as compared with 9.3 days for males in the same age group.

Table 3.3. Short-stay Hospital Discharges per 1,000 Persons and Average Length of Stay, United States, July 1963-June 1964

Age	Discharges		Average Length of Stay (Days)	
	Male	Female	Male	Female
Less than 15	75.4	61.0	6.1	6.1
15-24	69.8	225.5	9.3	4.6
25-44	87.2	219.1	9.2	6.1
45-64	159.8	149.3	11.8	10.0
65-74	219.2	196.3	12.8	11.9
75 and over	285.4	244.8	12.3	13.5

Source: (116, p.16).

Because of its intuitive plausibility, it is perhaps not necessary to belabor the point that changes in the age-sex composition of the population

will affect the demand for short-stay hospital services. The next question is, is the age-sex distribution of the population of the United States fairly constant or is it rapidly changing? In the former case, we might justifiably ignore the age-sex distribution in forecasting. The data in Table 4, comparing 1950 and 1960 census information, indicate that the age-sex distribution is far from constant.

Table 3.4. Percentage Distribution of the Total Population of the United States by Age and Sex, 1950 and 1960

Age and Sex	1960	1950
Male		
Less than 15	32.2	27.7
15-24	13.8	14.9
25-44	26.0	29.6
45-64	19.7	20.3
65-74	5.7	5.3
75 and over	2.6	2.3
Female		
Less than 15	30.4	26.5
15-24	13.4	14.8
25-44	26.3	30.3
45-64	20.1	19.9
65-74	6.4	5.7
75 and over	3.4	2.8

Source: (92, pp.146-47).

For both males and females there has been a relative shift from the middle age groups into the less than 15 and over 65 categories. This will have an impact upon demand for health services and upon the type of health services demanded.

The Price of Services

In view of some recent studies showing the price elasticity of demand for some categories of health expenditures to be near zero, it might seem

that the price of services is not an important explanatory variable.[2] The importance of prices is, however, dependent upon the reasons for this low price elasticity. If this is due to the inherent nature of the services, namely that the opportunity cost of not receiving the service may be very large (24, pp.948, 949), then one might ignore the impact of prices on demand. If, however, the inelasticity is due to the institutional character of the market in which the services are provided,[3] and one wishes to include these institutional characteristics and changes in them as explanatory variables, then prices themselves must be included as explanatory variables. Further, it is possible that the demand for hospital services is price inelastic, while the demand for services of some specific type of hospital is quite elastic with respect to price changes. This would be expected to be true for those classes of services which have close substitutes. For example, long-stay convalescent hospitals and nursing homes may face demand schedules which are very elastic with respect to relative prices.

To the extent that the manpower requirements for different types of hospitals differ, a change in the relative prices of services may have a significant impact upon overall manpower requirements. Unfortunately, it is one thing to state that the price of services is an important variable affecting demand and quite another to isolate the impact of price changes. Hospitals usually charge three rates (58, p.23), based upon whether the patient is in a private room, semi-private room, or ward. Ward service is generally provided for the person who is unable to pay for the full cost of

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[2]Feldstein (43, pp.34,40) found the price elasticity of demand for physicians services to be about 0.2, and for hospital service to be zero.

[3]Klarman (58, p.25) argues that the latter is true.

the service. The ward patient is expected to pay as much as he can but no more than the cost of providing the service. What then is the "price" of hospital services? The same problem arises with regard to physicians' services. Physicians have traditionally used a sliding schedule of fees, charging more for the same service to those individuals better able to pay. Thus there is price discrimination in the provision of the service as well as a perceived degree of product differentiation of the service itself. It may be that an individual demands not really a service but the physician himself (48, p.157). That is, the service may be inseparably vested in the individual providing it. This is not contradicted by the observation that perhaps what one really purchases from a physician is not a service but information (24, p.946). The value or perceived reliability of this information may still be vested in the person providing it. Thus in speaking of "physicians' services" we have aggregated many different types of services, each of which may be priced differently depending upon the patients' ability or willingness to pay for it or perception of value received. There does not exist a demand curve per se, and when we compute the price elasticity of demand for physicians' services we are not speaking about a rigorously defined concept. Generally what we arrive at is some measure of the percentage change in average price. However, average price can be changed in many ways, and it seems plausible that the demand response would differ depending upon the manner in which the average price changed. Our estimate of price elasticity is a purely empirical phenomenon and is probably a function of the time period over which the observations were taken. If this period is "long enough," we may derive an estimate of "average price" elasticity, assuming that over a "long enough" period the nature of the structure of

price changes tends toward some form of "representability." Note that this estimate of elasticity may be useless for short-term forecasting, as in a short time period changes in average prices may be caused by several different types of changes in price structures. It is possible that the price elasticity of demand for physicians' services is near zero for "small" price changes, but that "larger" price changes will cause a substitution of patent medicines and "home remedies" for the services of medical doctors. There is some theoretical reason to believe that the price of services may be a rather unreliable explanatory variable for use in predicting the demand for physicians' services and, to a lesser extent, for the services of short-stay hospitals.

Per Capita Income and Its Distribution

The third major variable which may be expected to affect the demand for health services is income and its distribution. Consider first the level of income. In a microeconomic sense, it appears that as a family's income increases, total expenditures on medical care increase, but in less than proportion. On the basis of expenditure data alone, it is impossible to assess the extent to which expenditure increases are due to increased use of facilities and services as income increases and the extent to which this may be a function of price discrimination. Table 5 lists some recent expenditure data. Note that the income figures are on a family basis, while expenditure figures are on a per individual basis.

Because of the difference in reporting units, no computation of income elasticity is possible. Further, the observed trend may be purely spurious. To the extent that average age of family members is positively correlated with income, the effect of increasing income may simply be a proxy for the

effect of increasing average age.

Table 3.5. Health Expenses (in Dollars) per Person per Year, by Type of Expense and Family Income, United States, July - December 1962

Income	Type of Expense				
	Total	Hospital	Doctor	Dental	Other
Less than 2,000	112	28	36	9	39
2,000 - 3,999	116	30	38	11	37
4,000 - 6,999	119	30	41	16	32
7,000 - 9,999	135	29	46	24	36
10,000 and over	178	34	60	37	47

Source: (125, p.22).

Stigler presented the following data on the income elasticity of expenditure on three classes of health services.

Table 3.6. Income Elasticities of Urban Families

Service	1919	1935-1936	1941
Physicians and oculists	.71	.82	.70
Dentists	1.53	1.24	1.12
Other medical care	1.07	.93	.72

Source: (89, p.27).

The income elasticity of dental services is apparently higher than that for medical care services as a whole. This has intuitive appeal, since the majority of dental services are probably postponable, which is not true in the case of physicians' services, for example. This would be expected to cause a higher income elasticity of demand for dental services. The mass of data available on health expenditures tends, however, to obscure a fundamental point. Data on the correlation of income and expenditure are not

very useful for deriving estimates of demand for services. For those families having annual incomes of less than \$2,000, 30.2% of the group incurred no health expense during the July - December 1962 period. For families having incomes of \$10,000 or more only 9.5% of the group incurred no health expense (124, p.24). A large part of this differential is due to the fact that various welfare agencies paid for the services received by low income families (124, p.4). Thus it is the correlation between income and utilization of services which is important for our purposes. Utilization of services and individual expenditures on services are not measures of the same thing, and for low income groups they may not even be highly correlated. Since expenditure on medical care is a consumption expense, all of the arguments against the use of measured income and in favor of "permanent income" (47) are applicable here. A very rigorous theoretical treatment of the effect of income on demand for health services would have to deal with the problem of income definition.

Income does appear to have an effect on the demand for medical care measured in physical units, as evidenced by data in the following tables. The magnitude of this effect may be quite small, however, and the nature of the correlation is not straightforward. Certainly the utilization of various categories of health services does not increase directly as income increases, if age-income correlation effects are removed.

Note particularly the fluctuation in physician visits per person for individuals aged 65 and over. Many of these persons are retired, and their income and their wealth may not be highly correlated. Those persons with very low wealth may have higher incomes, because they cannot afford to retire. If possible, we should consider wealth as well as income.

Table 3.7. Physician Visits per Person by Family Income and Age Category, United States, July 1963 - June 1964

	All Ages	Less Than 45	45 - 64	65 and Over
Less than 3,000	4.3	3.2	5.1	6.0
3,000 - 3,999	4.6	3.8	4.8	7.7
4,000 - 6,999	4.5	4.2	5.1	7.0
7,000 - 9,999	4.7	4.4	5.3	6.9
10,000 and over	5.1	5.0	5.1	7.7

Source: (102, pp.34,63).

Table 3.8. Patients Discharged From Short-stay Hospitals per 1,000 Persons, by Family Income and Age, United States, July 1963 - June 1964

Income	All Ages	Under 15	15-24	25-34	35-44	45-64	65 and over
Less than 2,000	136.4	55.3	163.4	163.2	148.4	138.3	178.1
2,000 - 3,999	145.6	63.8	204.1	196.2	132.4	167.9	198.7
4,000 - 6,999	128.0	72.0	167.6	175.7	134.5	151.3	189.1
7,000 - 9,999	121.7	69.7	119.0	187.4	134.0	149.3	179.9
10,000 and over	116.5	67.8	91.4	174.9	136.2	131.4	226.3

Source: (116, p.36).

Reading across the rows, i.e. the influence of age given income, discloses that the number of discharges increases as age increases, except for a "bulge" in the 15 - 34 year age groups. This is probably due to maternity cases, as discussed earlier, and can be handled by classifying the population by both age and sex. The cross classification by income does not alter the effect of age group, as previously discussed. Note, however, the irregularity of the effect of income given age. Individuals aged 15 - 24 years having family incomes of $2,000 - 3,999 had greater than double the number of discharges from short-stay hospitals than the same age group with family incomes of $10,000 or more. We could explain this by assuming that those in the $10,000-and-over category are persons still living with parents and

hence unmarried, while those in the \$2,000 - 3,999 category are primarily young married persons with a high incidence of maternity cases. Observe the remarkable constancy of discharge rates per 1,000 persons aged 35 - 44 having family incomes ranging from \$2,000 to over \$10,000, while for those persons aged 45 - 64 discharge rates decrease as income increases over \$2,000 per family per year. We could appeal to the argument that persons in high income brackets use more preventive services and hence fewer curative services. This still does not explain why there should be a difference between age groups 35 - 44 and 45 - 64.

We should be aware that we are simply using "casual empiricism" in looking at a summary table of data without testing to see if the differences we are discussing are statistically significant or not. Without having access to the original data, however, this type of testing is impossible. It is possible that some of the apparent incongruities in the data on hospital usage can be explained by considerations regarding hospitalization insurance. Hence I will defer further comment until after a general discussion on the institutional variables, I_{1t}.

Stigler's analysis (89) indicates that perhaps the utilization of dental services is more responsive to income differences than is the utilization of physician or short-stay hospital services. Recent data tend to corroborate this. In fact, it appears that the response of the number of dental visits per person to income differences is more regular and of greater magnitude than the response to age differences.

Table 3.9. Dental Visits per Person per Year, by Age and Family Income, United States, July 1963 - June 1964

Income	All Ages	Under 5	5-14	15-24	25-44	45-64	65 and Over
Less than 2,000	0.8	-	0.9	1.3	1.0	0.8	0.5
2,000 - 3,999	0.9	-	0.8	1.1	1.1	1.1	0.7
4,000 - 6,999	1.4	0.3	1.7	1.9	1.7	1.5	1.0
7,000 - 9,999	1.9	0.5	2.3	2.3	2.2	1.8	1.2
10,000 and over	2.8	0.7	3.2	3.5	2.8	3.0	1.9

Source: (127, p.18).

Health Insurance and Medicare

I will consider the effect of only two institutional variables on the demand for health services--health insurance plans and medicare. In the period from July 1962 to June 1963, 70.3% of all persons in the United States had some type of hospitalization insurance, and 65.2% had some type of surgical insurance (277, p.15). Coverage under both types of insurance appears to be positively correlated with family income, as shown following Table 3.10.

Table 3.10. Percent of Population by Family Income Having Hospital and Surgical Insurance Coverage, United States, July 1962 - June 1963

Income	Hospital Insurance	Surgical Insurance
Less than 2,000	34.1	28.8
2,000 - 3,999	51.9	46.8
4,000 - 6,999	79.0	73.9
7,000 - 9,999	87.3	83.2
10,000 and over	87.9	82.6

Source: (106, p.12).

There are widely varying schedules of benefits under different health

insurance plans, and it appears intuitively plausible that different income groups would be attracted to different types of plans. No reliable data are available on this point, but it appears that higher income families purchase insurance which pays larger benefits.

Of primary importance to this study are the effect of insurance on the utilization of health services and the trend in the portion of the population covered by health insurance. One survey (17, p.97) in July 1953 found that 57% of persons in the sample had some type of hospital insurance and 49% had some type of surgical or medical insurance. Comparison with the figures given above for the July 1962 - June 1963 period indicates that health insurance coverage has been increasing very rapidly, although the two figures are not exactly comparable due to definitional differences. Thus if health insurance is expected to grow, any impact of insured status on demand for services is of importance in forecasting the latter. If 70% of the population is now covered by hospital insurance, it might be expected that growth in this figure would be slow, as large segments of the population would be expected not to purchase insurance. Very low income families are a case in point. In any event, evidence appears to indicate that persons with health insurance use more health services than those who are not covered by insurance. In a survey conducted in July 1953, Anderson and Feldman (17) found that families with insurance incurred median costs of $145 per year for all health services, while those without insurance incurred median expenses of only $63. Deducting the amount paid by insurance still leaves $117 out-of-pocket expense for insured families, which is almost double the expense incurred by noninsured families (17, p.26). This could be due to price discrimination based upon ability to pay, causing the insured persons to pay higher prices for services received than is true for the uninsured.

Table 3.11. Hospital Admission Rates per 1,000 Persons, by Family Income, United States, July 1952 - June 1953

Income	Insured Persons	Uninsured Persons
Less than 2,000	210	90
2,000 - 3,499	160	90
3,500 - 4,999	130	90
5,000 - 7,499	130	80
7,500 and over	120	100

Source: (17, p.59).

Table 3.12. Surgical Procedures per 100 Person-Years, by Family Income, United States, July 1952 - June 1953

Income	Surgically Insured Persons	Non-surgically Insured Persons
Less than 2,000	15	4
2,000 - 3,499	10	4
3,500 - 4,999	8	6
5,000 - 7,499	9	6
7,500 and over	8	6

Source: (17, p.194).

This has some validity, especially in the case of the lower income classes, where persons without insurance receive free health services as indigents. However, this does not appear to be the whole story, as persons with hospital insurance also use more dental services than persons without hospital insurance.

It may be that some persons are simply more "health conscious" than others, and these persons are the ones that are attracted to health insurance. Klarman notes, "The insured spend more than the uninsured because

Table 3.13. Percent of Persons, by Family Income, Consulting Dentists, United States, July 1952 - June 1953

Income	Persons With Hospital Insurance	Persons Without Hospital Insurance
Less than 2,000	18	16
2,000 - 3,499	25	22
3,500 - 4,999	35	28
5,000 - 7,499	47	37
7,500 and over	59	47

Source: (17, p.200).

they want to, not because they have more illness and need more medical care" (58, p.35). This is a very weak explanation. In fact, it is more of an admission of inability to explain than an explanation in the true sense. I am not arguing that the statement is unture--merely that it remains to be explained why it is true. Certain types of insurance plans provide for flat-rate payments, as for example so much per day for a hospital room. Assume arbitrarily that the insurance plan pays for one-half of the cost of a hospital room. Since becoming insured is equivalent to receiving a price reduction on hospital services, abstracting from premium payments, it would be expected that utilization of these services would increase for an individual after he becomes insured.[4] However, given the low price elasticity of demand for hospital services[5], this alone will not cause total expenditures to increase. In fact, if price elasticity were zero, expenditure on

[4]Abstracting from any effect of initial increased use of hospital services caused by prior neglect of medical conditions in anticipation of achieving insured status.

[5]Near zero (43, p.40).

hospital services should be halved. It seems unrealistic to assume hospital services to be an inferior good, and the substitution effect of a price decrease should not cause an increase in demand for other health services. Therefore the income effect must be very large. However, I hypothesize that this effect is due not to the effectively lowered price of services but to the reduction of uncertainty caused by achieving insured status. Thus the insured family need no longer hold a reserve against a medical contingency and can "afford" to utilize nonessential medical services such as cosmetic surgery, dental prophylaxis, braces for children's teeth, and so forth. I view this as a budgeted reserve, not as an actual asset balance.

This provides an alternative explanation of results such as found by Weisbrod and Fiesler (136) that persons having "better" hospitalization insurance, defined as having more covered services and/or a higher schedule of payments for given services, utilized more hospital services than other insured persons. The more contingencies that are covered by insurance or the higher the benefit payments for a given contingency, the less the uncertainty regarding future medical expenses. Weisbrod and Fiesler also found that persons with more inclusive coverage tended to use more ancillary services which were covered in full, while the utilization of private hospital rooms was not significantly affected. Despite the fact that persons with "better" insurance also received a higher allowance for private rooms than other insured persons, there was still a charge involved to the user. Private room costs were not covered in full, causing effective coinsurance. Arrow (24, p.961) notes that coinsurance provisions are introduced in part to guard against moral hazard, or "misuse," of insurance benefits. Exactly what constitutes "misuse" brings us back to the concept of "need" for medical services, discussed in Chapter I. I do not propose to issue any ethical

judgments but merely to note that as long as some form of effective coinsurance is maintained, the use of services may not increase appreciably. Thus, in forecasting demand for services, perhaps we should differentiate between insurance providing full coverage and that providing only partial coverage. One final comment on Weisbrod and Fiesler's findings is to note that increased utilization of services by persons with "better" insurance was not found in all age and sex categories but was confined primarily to females over 55 years of age (136, p.131). This is additional evidence that the basic unit for forecasting demand for health services is population in an age and sex cohort group.

Medical care for the aged, or medicare as I shall subsequently refer to it, went into effect July 1, 1966. This is a federal government program to pay, through social security, part of the hospital bills of persons over age 65 and, for those electing the voluntary coverage, part of their doctors' bills. Included in covered services under medicare are up to 60 days in a hospital, for which the patient pays only the first $40, and an additional 30 days in a hospital for each spell of illness, for which the patient pays $10 per day. Payments for mental hospital treatment are limited to 190 days in a lifetime. Effective January 1, 1967, up to 20 days of care in a nursing home or convalescent section of a hospital is fully covered if preceded by hospitalization for three days or more. An additional 80 days of this care is available at a cost of $5 per day to the user. Up to 100 home visits by nurses or other health workers is covered for a period of one year after release from a hospital or nursing home, as well as 80% of the cost exceeding $20 of outpatient diagnostic tests in hospitals for each 20-day period of testing.

Persons may elect to pay $3 per month to receive additional benefits

under a supplementary program. This covers 80% of "reasonable charges" in excess of $50 for physicians' services; home health visits, even without prior hospitalization; and miscellaneous charges such as diagnostic visits, splints, dressings, and so forth (101, passim).

This rather detailed list of benefits is included in order to facilitate determination of which categories of health services we would expect to be affected by medicare provisions.

Prior to passage of Public Law 97, which brought medicare and medicaid[6] into being, several groups, notably the American Medical Association (32, p. 650), claimed that this program would cause such a large increase in the demand for health services as to render the existing facilities totally inadequate. However, "By mid-July (1966) ... it was apparent that the half-expected deluge of patients was not going to develop" (28, p.38). Chase, writing in early 1967, noted that "So far there has not been a sudden inundation of hospitals owing to these programs, but it is a bit early to say this won't happen" (32, p.651). Hospital utilization did increase about 5% in the last half of 1966. Before the advent of medicare, about 25% of all beds were occupied by those aged 65 and over, while the comparable percentage for the last half of 1966 was 30% (32, p.651)[7]. These changes are supposedly due to the influence of medicare.

Social security "experts" predict that in a few years we will have one-half million medicare patients in hospitals at any one time, and that medicare will pay one-fourth to one-third of the expenses of the average general

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[6] A provision for federal - state financing of health care for those on welfare and those not on welfare but threatened with bankruptcy due to medical costs beyond their means, i.e. the "medically indigent".

[7] Type of hospital not specified.

hospital (32, p.651). On the other hand, one may note that since various categories of home care are covered under medicare, hospital utilization by older persons could conceptually decrease after the advent of medicare. Since there is an element of coinsurance involved in medicare, it might be supposed that utilization of services might not increase much. This is assuming that the coinsurance provision is "effective" in Arrow's terms (24, p.961); i.e. that the payment required of the individual is large enough to prevent abuse of benefits.

In any case, I believe that the influence of medicare on forecasts of the utilization of health services can be handled in a manner analogous to the treatment of health insurance described below. In fact, until sufficient years pass to enable the forecaster to evaluate the impact of medicare, this effect can be approximated by studying the impact of private health insurance plans providing similar benefits on service utilization.

Proposed Forecasting Model

The forecasting equations I would suggest as a first approximation for deriving estimates of future service utilization are of the form $M_k = \Sigma_i\ b_0 + b_1N_i + b_2D_i + b_3P_k + b_4I_{ik}$. The b's are parameters to be determined, probably through multiple regression techniques, N_i is the number of persons in age and sex category i, D_i is average family income for persons in the age and sex category, P_k is an index of the price of health services of type k, and I_{ik} is the proportion of persons in the category covered by health insurance which covers services of type k. This would include both private health insurance plans and medicare. An obvious first step toward sophistication would be to have several I's for several different types of insurance coverage. The parameters can be determined from

time series data. Then forecasts are made of each of the independent variables. Assuming the parameters constant, we can then forecast M_k for future time periods.

No empirical test of this is attempted herein, for two reasons: (1) The data necessary to compute the regressions is not generally available for the time period of interest, namely 1950 - 1960. (2) My emphasis is on the conversion of forecasts of service utilization to forecasts of manpower requirements. The forecaster using the model developed in the other chapters of this analysis may well desire to use forecasts of service utilization derived by others, if reliable forecasts are available.

CHAPTER IV: TECHNICAL AND DEMAND COEFFICIENTS

The nature of what I have termed technical coefficients, denoted a_{jkt}, depends upon both the number of categories into which the demand for health services is divided and the number of occupations considered. This discussion is carried out in the frame of reference of seven categories of health services (Table 3.1) and twenty occupation categories, as listed in Table 7.1. The number of coefficients is, of course, determined by the ranges of the index numbers j and k. The determination of the range of k was discussed in Chapter 3. The range of j is determined by the use to which the results of the forecast will be put. If we wish to discuss the implications of the results for public policy regarding training, we should define n, the limit to j, in such a manner that occupations involving different training requirements are indexed separately. We would probably not want to combine physicians and nurses in the same category, because the training requirements are obviously very different. The limit to the decomposition of employment into occupation categories is arbitrary. For example, I am considering all physicians in the same category. We could break this down further into general practitioners and the various types of specialists, since the training needs of these categories differ. The determination of the number of occupations considered is also influenced by research funds available and, unfortunately in practice, by data availabilities.

Consider first the determination of A_B, the technical coefficients for the base year. It is obvious that many of these will be zero; that is, the number of physicians needed to provide dental services would be expected to be zero, and so forth. The determination of the nonzero a_{jkB}, and the

determination of which of these are zero, can be accomplished by analyzing several types of data. We can examine national data on employment by occupation in hospitals, for example, and using this together with national data on hospital utilization can derive a_{jkB} for hospitals. However, this may not always be possible because of data limitations. We may still estimate a_{jkB} from partial data--for example data from some "representative" geographical area, group of hospitals, and so forth. These latter estimates are not as easily defended as being "correct" but may be extremely useful for forecasting. Many of the more detailed analyses of health personnel have been carried out on subnational areas.

We could approach the problem from the other end. Data published by the American Nurses' Association, for example, indicate the percentage of their members employed by short-stay hospitals. Correcting this data for over-reporting due to inactive members and for under-reporting due to nonmembership in the association by some individuals in the profession provides another estimate of a_{jkB} in short-stay hospitals. Whenever possible, it is, of course, desirable to cross check coefficients derived from all available data for consistency. In any event, we can derive some estimate of employment in each occupation used in providing each category of health service, denoted x_{jkB}. Then $\Sigma_k\, x_{jkB} = X_{jB}$ is the total employment in occupation j during the base period t = B. Dividing by m_{kB} we obtain $a_{jkB} = x_{jkB}/m_{kB}$, or $x_{jkB} = a_{jkB}\, m_{kB}$. Substitution yields $X_{jB} = \Sigma_k\, a_{jkB}\, m_{kB}$, or in matrix notation, $A_B M_B = X_B$. Note that we have no particular interest at this point in x_{jkB} but rather in a_{jkB}. If we can derive the latter more directly without the use of x_{jkB}, there is no objection to doing so. The reasoning behind this manipulation is that it is easier to predict the a_{jk} for some future time period than it is to predict the X_j or the x_{jk} directly.

X_j has a very strong dependence upon M_k, and M_k may be a very stable function of variables that are not as directly related to X_j. In deriving X_j from M_k, I feel that a_{jk} is again a more stable function of a smaller number of variables than x_{jk}.[1]

Selection of Independent Variables for Forecasting Changes

There are several ways to forecast what the technical coefficients will be at some future time period $t = T$. As previously indicated, the simplest assumption is to let $a_{jkT} = a_{jkB}$. This will furnish a crude approximation to X_T. However, I wish to be more precise than this. Another assumption is to make a_{jk} an explicit function of time. This function can be estimated by regression analysis if we can generate a time series of values for each technical coefficient for some previous time periods. At least two observations are needed for estimation of the function. This method has some merit and will be used for most of the coefficients which are forecast in Chapter 7. Note, however, that we are simply stating that some given coefficient is a stable function of time, and that we assume it will continue to change in the future as it has in the past. We do not directly offer any explanation of why this relationship holds or of what influences cause the coefficient to change as it does. Since these are not specified, it is not exactly clear just what it is that we assume will be the same in the future as it has been in the past, and it is impossible to evaluate the reasonableness of the assumption. It is still true that the simple function of time provides the best forecasts in many instances, but beyond this the

[1]Friedman notes that an unstable function can actually be viewed as a perfectly stable function of an indefinitely large number of variabl...

approach is singularly uninformative.

Finally, we may make the a_{jk} functions of some exogenous variables. (46, p.13) We could, of course, convert our system from a simple accounting identity into a system of simultaneous equations by letting the number of physicians required per 100 patient-days in short-stay hospitals be a function of the number of registered nurses present per the same variable, for example. This method will not be used herein. Although it is conceptually appealing, the estimation of the rates of substitution between occupations is operationally very difficult. These substitutions are not ignored, but they are accounted for indirectly, as indicated later.

Several types of exogenous variables suggest themselves as important, a priori. Capital substitution for labor may be important for several occupations. It might be expected that, roughly speaking, the greater the amount of capital investment in equipment per patient, the greater the number of patients handled per hour or per day by dentists, for example. We are here using a form of capital-output ratio as an explanatory variable. Methods of organization may be important. If group practice is an increasing phenomenon, physicians may be able to handle more patients per hour due to more efficient operation of the classification and screening of patients as well as of the bookkeeping function. On the other hand, the number of patien handled per physician per year may be lowered as group practice increases, as physicians take advantage of the greater flexibility to obtain more leisure time. Methods of operation are extremely important. Certainly physicians handle more patients per day now that house calls are the exception rather than the rule. This last change was probably brought about by better transportation facilities for the average individual in the population as well as a general shortage of doctors.

Certain occupational classifications have duties other than patient care, notably some part in the training function, either as teachers or as trainees. Thus the number of interns in hospitals is in part a function of the patient load or demand for services and in part a function of the forecast requirement for physicians in the future. This phenomenon can be handled in the model in several ways. We could add a constraint to the recursive program which requires that the number of interns must be greater than or equal to a given magnitude. Alternatively, and perhaps most correctly, we could add a component to M_T which we could label "training," derive an estimate of the total number of hours of training required, and compute technical coefficients for this activity. We can otherwise make an allowance in the technical coefficients for changes in the percentage of employees in an occupation-service category that are engaged in training activity. If it is expected that the training activity will increase, the technical coefficients will reflect this as an effective decrease in productivity in rendering services to patients. Admittedly this tends to camouflage the true nature of the change which is taking place, but the last method is used herein because of computational simplicity.

If changes in the percentage of hospitals in an ownership and control category are anticipated, this will have an impact upon technical coefficients for hospital personnel. Proprietary hospitals use less labor per admission than do other types of hospitals, as evidenced in Table 4.1. There is some evidence which indicates that the percentage of patient-days by type of ownership and control category is changing. Primarily there appears to be a shift from proprietary to nonprofit and governmental hospitals. This information is shown in Table 4.2. The 1942 figures on governmental hospitals are probably affected by wounded servicement.

Table 4.1. Ratio of Personnel to 1,000 Admissions in Hospitals, by Type of Hospital, United States, 1950 and 1952

Ownership and Control Category	1950	1952
All hospitals	41.4	40.4
Nonprofit hospitals	41.7	39.8
Proprietary hospitals	25.4	25.6
Governmental hospitals	48.3	49.4

Source: (55, p.45).

Table 4.2 Percent of Patient-Days per Year in Hospital Ownership and Control Category, Selected Years

Ownership and Control Category	1942	1949	1952
Nonprofit hospitals	50.0	55.0	53.1
Proprietary hospitals	5.3	5.6	5.0
Governmental hospitals	44.7	39.4	41.9

Source: (55, p.20).

Hospital personnel needs per patient-day vary due to two factors. The larger hospitals appear to enjoy some economies of scale in the patient care function, but because of increased participation in the teaching function they employ more total personnel per patient-day.

The presence of scale economies may be easily inferred from the data on the administrative and auxiliary categories of nursing personnel. It is tempting to state that there are no economies of scale in the "other professional" category, composed primarily of general duty nurses, and that the number employed per 100 patient-days in this category is not affected by size of hospital. However, it is still possible that there are economies of

scale in patient care, but that in the larger institutions more of the general duty nurses spend part of their time on the teaching function.

Table 4.3. Nursing Personnel per 100 Patient-Days, Nonprofit Hospitals, 1952

Personnel Class	All	Bed Capacity: Less Than 50	51-100	101-200	201-300	301 and Over
Total	126.9	107.2	114.6	131.4	132.4	128.6
Administrative	15.0	17.7	17.7	15.5	13.6	13.2
Full-time instructors	1.8	0.2	0.6	1.9	2.2	2.2
Other professional	32.4	31.9	33.2	34.4	32.5	30.3
Students	34.3	2.0	12.1	36.4	43.8	43.0
Auxiliary personnel	43.4	55.4	50.1	43.2	40.3	39.9

Source: (55, p.208).

Changes in average per capita income, or in the distribution of income, may affect the technical coefficients as well as the demand for services. This is due to the aggregative nature of the components of the service vector. The best example of this is the demand for dental services. The income elasticity of demand for dental services as a whole is greater than unity (218, p.27) and for certain sub-components of dental services such as prophylaxes may be very high. Assuming for the moment that this is true, then an income-induced increase in the demand for dental services could cause a greater percentage increase in the demand for dental hygienists than in the demand for dentists. This again is an argument for greater disaggregation of the service vector but can be handled by forecasting differential changes in the technical coefficients for different occupations within a service category.

Productivity Changes

Productivity is customarily measured as output per man-hour, man-day, and so forth. In the case of the health industry this becomes difficult, since the product is a service, and in most cases a highly differentiated service. We can assume this away if we wish and speak of aggregates or averages, such as "average number of patients per day for private practitioners." In speaking of changes in the above magnitude over time, we assume that the case load mix is the same for all time periods and that approximately the same group of physicians is included in the denominator. However, this still leaves the problem of the quality of medical care. If the average number of patients served per day per physician increases, this could be due to better diagnostic facilities, improved dissemination of an increased body of medical knowledge, better trained physicians, improved drugs, better trained assistants, or increased use of assistants--all of which may indicate an increase in productivity. Alternatively, this could be evidence of a deterioration in the quality of the service rendered.

It may be argued that in a pure personal service, any increase in output per-man hour represents a decrease in the quality of the product. If a barber cuts four heads of hair in an hour instead of three, the quality of the product may be definitionally decreased. The service rendered by the barber may not be simply the removal of excess locks but the feeling of being pampered, pleasant conversation, and so forth enjoyed by the consumer. An analogous argument could be constructed for physicians, nurses in hospitals, and other occupations, although the consumption of medical services is not usually pleasurable.

Productivity increases can be unambiguously isolated only if the quality of the service is unchanged, but it is even conceptually impossible to define

the quality of service in the case of many health services. If we were to define some index of health, as discussed in Chapter 1, we could define productivity changes as changes in output per unit input subject to a constant index of health (134, p.185). In so doing, we would have assumed that the index of health is the key variable in some social welfare function, and that individual utility considerations similar to that in the barber example are irrelevant.

For our purposes, it is not really necessary that we meet the above conceptual problems head on. We simply wish to forecast changes in technical coefficients without regard to whether these are due to changes in productivity in the true sense or to changes in the quality of the service rendered, <u>provided</u> that a sufficient basis for prediction exists without this knowledge. Most of the productivity data available relate to physicians.

Table 4.4. Estimates of Output per Physician, 1935 - 1951

Year	Index	Year	Index
1935	100.0	1944	212.7
1936	110.7	1945	234.4
1937	114.3	1946	212.9
1938	110.8	1947	214.6
1939	114.0	1948	220.5
1940	119.8	1949	225.4
1941	133.4	1950	233.4
1942	167.8	1951	242.1
1943	210.6		

Source: (50, p.11).

These data were derived by deflating an index of mean gross income per physician by the index of physicians' fees. Abstracting from considerations regarding the reliability of the data, this is a valid index of output per physician. It is not, of itself, a valid indication of an increase in

production efficiency in the provision of physicians' services. That is, we cannot infer an increase in the total output over total input ratio. Average hours worked pe: week may have increased, or the total output, if measured in both quantity and quality terms, may not have increased as much as is assumed. It does not appear that hours worked per week have increased. In 1949, the average private practitioner worked 58.3 hours per week (78, p.147). In the early 1930's, physicians worked "56 to 70" hours a week (40, p.220). While no exact figure is available for the 1930's and 1940's, it appears that the increase in hours worked for physicians has been small, and there may have been a decrease. I will not delve into changes in the quality of care rendered by physicians as the problem is much too complex to be disposed of in a few paragraphs. If there have been changes in quality, I will simply assume that this trend will continue into the future, making productivity figures such as Garbarino's useful for predicting changes in the technical coefficients for physicians.

A similar index can be constructed for dentists.

As Garbarino noted regarding his productivity series for physicians (50, p.13), the series on output per dentist is only a crude approximation of the variable in question. Changes in the cost of providing services not reflected in fee changes are incorporated into the productivity series, as we are using gross income. If the dentist was able to collect a larger percentage of his billings in certain years than in others, this effect is also included in our measure of productivity.

It may be noted in both series that productivity was higher during the late war years than in the immediate postwar years. This is assumedly due primarily to the wartime shortage of physicians and dentists in private practice.

Table 4.5. Estimates of Output per Dentist, 1935 - 1951

Year	Mean Gross Income[a]	Index of Mean Gross Income	Index of Fees	Index of Output per Dentist (1935 = 100)
1935	2,485	100.0	100.0	100.0
1936	2,726	109.7	100.1	109.6
1937	2,883	116.0	102.3	113.4
1938	2,870	115.5	102.6	112.6
1939	3,096	124.6	102.8	121.2
1940	3,314	133.4	102.8	129.8
1941	3,782	152.2	103.1	147.6
1942	4,625	186.1	105.1	177.1
1943	5,715	230.0	110.6	208.0
1944	6,649	267.6	116.7	229.3
1945	6,922	278.6	121.7	228.9
1946	6,381	256.8	128.9	199.2
1947	6,610	266.0	139.6	190.5
1948	7,039	283.3	147.1	192.6
1949	7,146	287.6	153.1	187.9
1950	7,436	299.2	156.7	190.9
1951	7,820	314.7	162.6	193.5

Source: Column 1, (112, p.47), column 3, (61, p.1055).

[a]Nonsalaried dentists only.

Productivity changes for other categories of health personnel are not as easily estimated, since factors other than fees for services are included in the price index series. A series is available on the prices of optometric examinations and eyeglasses, for example, but it is impossible to ascertain the relative amount of increase due to increases in the price of services versus increases in the price of the physical commodity.

Certain changes in technical coefficients are matters of custom rather than economic factors. Dentists have traditionally used few assistants (77, p.187). "Dentists employing one assistant average about one-third more patients than those without such employees" (77, p.186), while the weighted average salary for dental assistants and hygienists was only 26%

of average salaries for dentists in 1950 (Tables 7.1 and 7.16). About one-fourth of the average dentist's time is devoted to prophylaxis, which could be performed by a dental hygienist (77, p.187). If dentists are truly in short supply, one would expect greater utilization of assistants. The impediment does not appear to be economic but institutional or a matter of "custom." One is left with the impression that a large increase in the demand for auxiliary dental personnel could occur at any time, but that it is impossible to forecast the timing of the occurrence.

Demand Coefficients

Most of the comments made above apply equally well to technical coefficients or demand coefficients. In fact, a technical coefficient may be termed a naive proxy for a demand coefficient. Demand coefficients as used herein represent a type of "ceteris paribus" demand; that is, they reflect the number of persons in an occupation that the health industry would desire to employ, providing that employment in other occupations is at certain levels. It may be impossible, because of the total resource constraint, to achieve this level of demand for all occupations simultaneously. This factor is introduced into the analysis through the constraint matrix in the recursive program.

The demand coefficients for the base year, denoted a^*_{jkB}, can be derived in various ways. We can derive estimates of x^*_{jkB} from survey data on job vacancies, for example, and compute $a^*_{jkB} = x^*_{jkB}/m_{kB}$. The procedure used for most coefficients in Chapter 7 is to estimate excess demand as a percent of employment for each occupation-service category and use this to estimate x^*_{jkB} and then a^*_{jkB}. Note that it is again the coefficient which is of interest, and if we can estimate this more directly without estimating

x^*_{jkB} first it is desirable to do so.

Excess demand itself can be measured in different ways. Budgeted vacancies is a fairly good measure of excess demand and is in fact used in Chapter 7 as an estimate of that magnitude. Intuitively, budgeted vacancies may in some cases be smaller than the "difference between actual employment and the number of persons who would be employed at prevailing wage rates if no supply constraint were present." Excess demand by this definition can be measured only by survey techniques. Since this is impossible if the base period is not the present, various sources are utilized in the empirical section to estimate excess demand in 1950.

Many of the comments made regarding the forecasting of technical coefficients apply to forecasting demand coefficients as well. If time series data on employment plus budgeted vacancies are available, one may project an estimate of total demand over time. This type of information is, however, very difficult to find for most occupation-service code categories. To the extent that information on exogenous variables such as productivity changes is available, this can be used to forecast demand coefficients, as previously discussed in the section on the forecasting of technical coefficients. In fact, this type of information is more pertinent to demand coefficient forecasting than technical coefficient forecasting.

An extremely crude method is used in Chapter 7 to forecast changes in demand coefficients. If a forecast technical coefficient for some future period is greater than the demand coefficient in the base period and the forecast of the technical coefficient is "reliable," we know that the demand coefficient must be at least as great as the technical coefficient at this future point in time. Employment cannot exceed demand. However, the demand coefficient may be larger than the technical coefficient by an

undetermined amount. Thus the practice of using the forecast technical coefficient in 1960 as the forecast demand coefficient for that year if the former is greater than the demand coefficient in 1950 yields a conservative estimate of demand. This method is used extensively in Chapter 7 when no other information is available. The error introduced by this crude estimate is not very serious in the case in point, because in most cases excess demand is so large that even the crude technique forecasts a substantial excess demand. With other data configurations a more precise estimate of demand coefficients may be necessary to gain forecasting accuracy.

CHAPTER V: LIMITS TO SUPPLY CHANGES

The discussion of estimating supply constraints for the recursive program is conveniently divisible into a discussion of upper bound constraints and lower bound constraints.

Upper Bound Constraints

The maximum percentage increase possible in the supply of personnel is dependent upon the additions to and deletions from supply during the period in question. For occupations having some training requirement, additions can be estimated by analyzing data on the output of training institutions. At this point two alternatives are open to the researcher. First, one may conduct the analysis in terms of gross or potential changes. In this case, anyone receiving a diploma from a recognized school of occupational therapy, for example, would be considered in addition to supply. Alternatively, we may attempt to estimate the percentage of new graduates who will actually seek employment as occupational therapists. We can attempt to forecast "actual" rather than "potential" additions to supply.

Conceptually, the "actual" additions are of more interest than the "potential" additions, but the former magnitude is very difficult to estimate. We cannot deduce the magnitude of potential additions by analyzing empirical data on the number of graduates who actually obtained employment in the occupation for which they were trained. If supply exceeds demand, we would be using a demand figure as an estimate of supply. In the absence of data on the reasons why some persons trained for a certain occupation actually become employed in some other occupation, we cannot get an accurate estimate of "actual" supply. Because this type of data is usually not available, I recommend the use of gross supply information in

between demand and actual employment by the marginal value product of the average person in the occupation. It is, of course, impossible to operationally measure the marginal value product, so it may be assumed that wage rates are approximations to the marginal value product. This is a rather heroic assumption, but since multiplying the objective function by any positive constant has no effect upon the solution values, we need only assume that relative wage rates are measures of relative marginal value products. This assumption is more reasonable. If we denote the relative wage rate for occupation j by r_j, our objective function becomes minimize $\Sigma_j\ r_j(x^*_{jT} - x_{jt})$.

This form still has some deficiencies, however. For an occupation which may be declining over time, i.e. one such that x^*_{jT} is less than x_{jB}, an unrealistic adjustment path is forced by the restriction $x_{jt} \leq x^*_{jT}$. Essentially the entire decrease in employment must take place in the first period rather than allowing for a gradual rate of decline. That is, x_{jB} will decline to something less than or equal to x^*_{jT} by period $t = B+1$. This has repercussions on other occupations as well, assuming that the total resource constraint is binding. Unrealistic adjustment paths are likely to be the result for a number of occupations.

This problem may be avoided by using a quadratic objective function and dispensing with the constraint $x_{jt} \leq x^*_{jT}$. The objective function is now of the form minimize $\Sigma_j\ [r_j\ (x^*_{jT} - x_{jt})]^2$. It is apparent that any solution in which $x_{jt} > x^*_{jT}$ is nonoptimal, since the value of the objective function is lowered by the simple expedient of reducing x_{jt} until it equals x^*_{jT}. Given the nature of the total resource constraint, this action will also free resources which can be used to hire additional personnel in other occupations where excess demand is positive, further reducing the value of the objective function. Thus with a quadratic objective function a

forecasting for most occupations.

For some occupations, such as professional nurses, where it is known that large numbers of trained persons drop out of the labor force for reasons other than inability to find a job (78, p.204), the gross supply concept is not very meaningful. For these occupations an adjustment must be made for those persons who will not become employed in the occupation for which they were trained. The problem is most acute in those occupations where the additions are primarily young females. A large proportion of these persons will leave the labor force to be married or to raise children, and then perhaps re-enter the labor force again at a later date.

There are several ways in which this effect can be handled in forecasting supply. We may simply estimate a large enough "dropout" rate to account for persons leaving the potential supply in an occupation for any reason whatsoever, including "dropouts" among those persons newly trained. This method is used for forecasting the supply of dieticians and nutritionists in Chapter 7. Alternatively, we can estimate survival rates, giving the percentage of the graduating class which is expected to be active in the occupation at points in time a stated number of years after graduation. This method is used for professional nurses in Chapter 7 (78, p.204). This latter method is conceptually superior to the former but cannot be widely applied because such data exist for a very small number of occupations.

For most occupations in this analysis, data on gross additions are derived by projecting a trend in the number of graduates of approved courses of training. In most cases a linear trend is extrapolated, but in some "growth" occupations a nonlinear trend is used. In order to justify the use of a nonlinear form, the data available in the base period should exhibit tendencies toward nonlinearity, <u>and</u> some nonempirical evidence

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should be avilable which indicates that the occupation in question is in fact a "gorwth" occupation, i.e. that the number of additions is expected to increase at an increasing rate. Simply allowing the data to dictate the nature of the regression equation changes the confidence level of the forecast and makes the entire procedure suspect. The ex ante hypothesis for most trends extrap lated in this study is linearity. The justification for other forms of equations is based upon nonempirical information, or is explained at the point in the paper where the forecast is made.

In cases where "reliable" forecasts of future additions to supply in an occupation are available from outside sources, these may be used instead of some self-generated forecast. The supply of dentists is forecast in this manner in Chapter 7. It may be that a forecaster using the present time as the base period would wish to survey heads of training institutions regarding the magnitude of expected future additions to supply.

If one uses the concept of gross or potential supply, then it is proper to use death rates as the measure of deletions from supply during a given time period. Mortality rates are decreasing over time in the United States (93, pp. 28 - 29). The decreasing trend appears to apply to all age and sex categories, although it is possible that an increase would be found for some cohort groups if another breakdown were used. In any case, deaths per 1,000 persons in an age and sex category are not constant over time, and it becomes necessary to forecast changes in these rates. This can be accomplished by various means, or outside forecasts made by demographers may be used.

A sophisticated estimate of deaths in any occupation during some time period t would be derived as follows. Historical data would be gathered on deaths per 100 persons of a given age and sex in the occupation in

question. If reliable forecasts of the death rate are available, these may be used, or the forecaster may generate his own. Denote this death rate by d_{ijst}, where i indexes age, j refers to the jth occupation, and s denotes sex. Rates must be expressed per some unit time period, and I define d_{ijst} as the number of deaths per 100 individuals in the category in the time interval from time t-1 to t. Let x_{ijst} denote total personnel in category ijs at time t, and g_{ijst} be additions to the category in the time interval from time t-1 to t. Then $x_{ijst} = x_{i-1,js,t-1} (1 - d_{i-1,jst}) + g_{ijst}$, and total deaths in occupation j from time t-1 to t = $\Sigma_i \Sigma_s (x_{i-1,js,t-1})(d_{i-1,jst})$.

Several simplifications of this procedure may be used. The age distribution of employment is seldom known by single years of age. Census data (95, pp. 37 - 52) is generally reported by five-year age categories. We can convert this to an estimate of single years of age by assuming a rectangular distribution of persons within a category. Alternatively, we can use the index i to denote five-year age categories rather than single years of age. Then $x_{ijs,t+k} = x_{ijs,t+k-1} (1 - d_{ijs,t+k}) + g_{ijs, t+k}$ for k = 0, 1, ..., 4, and $x_{ijs,t+k} = x_{i-1,js,t+k-1} (1 - d_{i-1,js,t+k}) + g_{ijs,t+k}$ for K = 5, 6, ..., 9. That is, the number of persons in age group 30 - 34 is "transferred" to age group 35 - 40 only at five-year intervals.

To work with either single years of age or five-year age categories in this manner requires that the age distribution of new entrants, or additions, be known. This information is not generally available. For this reason the analysis in Chapter 7 simply assumes the age and sex distribution to be constant over the forecast period. Experimentation with some occupations using a "reasonable" hypothetical age and sex distribution for additions discloses that the error introduced by the assumption of constancy is very small.

For some occupations which have been in existence for only a short period and hence have a very youthful composition, such as sanitarians, a changing age composition is necessary if the forecast period is much over ten years. Even for those occupations, the error introduced by assuming a constant age and sex distribution is very small for a ten-year forecast period.

If the analysis is conducted for some sub-national area, the problem of migration becomes important. For national forecasts, it may be assumed that net migration of personnel is negligible for most occupations. The analysis in Chapter 7 considers migration for only one occupation, namely physicians. Net migration can be handled by simply incorporating it into g_{ijst}.

One criticism which may be leveled at the method used to derive the supply constraints in the empirical portion of this paper is that no explicit allowance is made for retirements. This is in keeping with the concept of gross or potential supply. Persons over age 65 are still at least "potentially" available for work. It may be that some reduction should be made, such as considering three persons over age 65 as equivalent to one under this age limit. This ratio can be estimated from historical data if it is available. However, if this reduction in potential supply is estimated, then consistency would dictate adjusting for persons active in the labor force but not working in the occupation for which they were trained, as well as persons removed from the labor force prior to age 65 for reasons other than death.

Various tables in the section of Chapter 7 devoted to estimating the supply constraints show that substantial numbers of persons in the health occupations are still employed long after age 65. Since data do not exist

regarding retirement rates, the entire analysis is conducted in terms of gross supply. There is nothing wrong with this, as long as any interpretation of the results is carried out with a clear conception of the nature of the input data. A forecaster using the model developed herein would probably find his results more easily applicable to decision making if a net concept of supply were used. Certainly the supply estimates contained in Chapter 7 are crude, but it is not my purpose to develop a sophisticated model for forecasting supply changes. I am attempting to show how to use supply and demand forecasts together to analyze relative shortages in various occupations. Several different methods of forecasting supply are compatible with the overall scheme.

For some occupations which have very low or no training requirements as a prerequisite for entry, no upper bound constraint is estimated. This is an oversimplification in that an upper bound constraint does exist de facto. However, this limit is very difficult to estimate without going to some type of full "general equilibrium model of the labor market," which is beyond the scope of this paper. Even though dental office assistants, for example, require no formal training beyond high school to gain entry to the occupation (84, p.704), some upper bound is present in the form of the total number of persons in suitable age and sex categories present in the population. The true constraint is much lower than this, in general depending upon relative wage rates and working conditions between the occupation in question and all possible alternatives. If the health industry wishes to hire more dental office assistants, it can assumedly do so. This can be accomplished by raising wage rates, if not by other means. The nature of the resulting adjustment process depends upon the response by competing industries or occupations. Considering forecasts

of only ten years into the future and changes in demand of minor magnitude relative to the size of the total labor force, it is probably not unrealistic to consider supply unconstrained for these occupations.

Actually the entire problem of decreases in supply due to causes other than death and upper bound constraints for occupations without training requirements for entry are best handled in a model which allows explicitly for a supply response to demand and employment conditions. This would entail the use of a two-way recursive system in which wage rates and their determination would play a much more important part than they do in the model herein presented. This two-way recursive model would be much more precise theoretically, but would probably not be as useful in forecasting for the intermediate term period. Supply response to demand conditions is essentially a long-run phenomenon. Since the stated purpose of the model developed in this paper is to provide information useful in planning for training purposes, e.g. for affecting supply, it may appear that the model is inappropriate for the use for which it was designed. I believe this is untrue, as each year or two years or five years, as resources permit, the parameters may be re-estimated and another forecast made for ten years into the future. Even if a long-term forecasting model is used, say to forecast twenty or thirty years into the future, provision for interim re-evaluation should be made. It is inherent in forecasting that the degree of confidence decreases the farther into the future the time period for which the forecast is made.

Lower Bound Constraints

Several types of lower bound constraints can be used. These represent the "smallest magnitude that employment can be in the period in question."

For occupations in which most persons are self-employed, a reasonable lower bound for period t is employment in t-1 minus forecast deaths. In the short run, it may be impossible to reduce employment below this figure unless some type of annual licensing is required and the number of licenses is restricted as a policy measure.

Other occupations may be viewed as having no positive lower bound constraint, as the health industry could conceptually abolish some occupational classification and cause all persons previously in this occupation to seek other employment. Alternatively, lower bound constraints for all occupations could be estimated as suggested above for occupations composed primarily of the self-employed.

Lower bound constraints are useful primarily to prevent the recursive program from giving absurd results. In most cases these constraints are inoperative. In the analysis in Chapter 7, no lower bound constraint is ever binding. In the event that the program does give "unrealistic" results, for example a solution that entails cutting employment in some occupation in half in one year, some "reasonable" constraint can be added. One might arbitrarily specify that employment in period t+1 must be at least 90% of employment in period t, for example. "Informed judgment" can be used to specify what a reasonable rate of orderly decline in employment in an occupation might be, in the event that a problem of this sort occurs. Employment in most occupations in the health field is growing, not declining, and a forecast of an "unreasonable" rate of decline probably represents an incorrect specification of the model or an inaccurate estimate of some parameter(s). A problem of this type should be rectified by correcting the cause of it rather than simply constraining the model.

Other Constraints

The forecaster is free to add other constraints to the model if it is found that these exist in the health industry. For example, it may be desired to employ at least one practical nurse for every professional nurse in certain classes of hospitals. If hospitals rely upon such a rule of thumb in hiring personnel, this may be converted to a total employment basis and added to the program as a constraint. If a law is passed requiring at least one sanitarian to be employed by every municipal health department in municipalities over a certain size, a computation can be made of the total number of sanitarians thus required and the result entered as a lower bound constraint in the program. In adding constraints of this nature, only one principle must be adhered to. If a lower bound constraint is ever higher than the upper bound constraint on that same variable, no feasible solution will exist. The addition of constraints can cause infeasible solutions in other less trivial ways as well. The forecaster is probably best off ignoring problems of this type until they occur, and then modifying the model. An infeasible solution is evidence of an improperly specified model.

CHAPTER VI: OBJECTIVE FUNCTION AND TOTAL RESOURCE CONSTRAINT

There are several types of objective functions which could be used for the model developed herein. There is little theoretical basis for selecting one over another, and ideally one might test several variations to attempt to isolate the one giving the best results. The purpose of this analysis is to find some objective function for use in industries, such as the health industry, for which the traditional profit maximization hypothesis is inappropriate. Cost minimization subject to an output constraint is really a form of profit maximization, and Baumol's sales maximization hypothesis (27, pp. 301-3) intuitively seems inappropriate. There is no reason why firms within the health industry should be concerned about concepts such as the "share of the market." These are "economic objective functions" which have been proposed for the _firm_. Since my model is explicitly macroeconomic in character, it is not surprising that these objectives are not useful as decision criteria.

Very little has been done in economic theory regarding objective functions for an industry. An industry is, after all, not a decision making unit. Yet I would maintain that because of the large amount of public funds expended for health, and because of the great degree of control exercised over the health industry by various levels of government in licensing facilities and personnel, an objective function for the health industry as a whole is quite appropriate.

The preceding argument may appear to be academic in that the nature of my proposed objective function should be applicable to almost any industry. All of the possible objective functions that I will propose relate to minimizing some function of excess demand. The argument regarding the validity

of the industry as a decision making unit is not purely academic, however, for the sum of several individual optima need not be, and usually is not, equal to some overall optimum. Even though the minimization of some function of excess demand may be a reasonable objective function for the individual firm regarding its labor market decisions, this does not make it a reasonable objective function for an industry composed of many decision making units <u>unless</u> evidence can be presented to indicate that there is some overall decision making body which compensates for the actions of individual units in the industry in question in such a manner as to cause the solution to the overall objective function to be approximated. I claim that the health industry is in this latter class, although I admit that my concept of the "public sector" as being the compensating decision making unit is a bit nebulous.

Variations of the Objective Function

The simplest objective function which comes to mind is minimizing $\Sigma_j (x^*_{jT} - x_{jt})$, i.e. minimizing excess demand, where demand is estimated only for some target date t = T rather than having separate estimates for each year from t = B to t = T. Because employment cannot exceed demand, and because true minimization of this function would dictate making excess demand as negative as possible, it is necessary to add a constraint of the form $x_{jt} \leq x^*_{jT}$. One difficulty with this formulation is that it assumes that a shortage of one physician is precisely as serious as the shortage of one hospital attendant. Intuitively, assuming that wage rates bear some relation to the marginal value product of the worker involved, a shortage of one physician should be more serious than a shortage of one hospital attendant. This problem may be rectified by weighting the difference

developed in the preceding chapters, an attempt is made in this chapter to predict employment by occupation in 1960 based upon 1950 base period data. This is a semi-simulation process in that the 1960 figures on demand for health services are accepted as data. Thus the only part of the model being tested here is the conversion of data on demand for services into a fore-case of employment by occupation. Since the data on employment by occupation in 1960 are known at the time the test is performed, there is always a possibility of bias. I have endeavored to eliminate this bias insofar as possible, but it should be recognized that the test of the predictive ability of the model performed herein is a rather weak test. A forecaster operating in 1950 might have included a provision for the effects of some type of medical and health insurance for the aged financed from governmental revenues, on the supposition that this would be legislated prior to 1960. Having the advantage of hindsight, I know that medicare was not legislated until after 1960 and hence ignore the impact of this. It should be obvious that there are several potential advantages to hindsight, which may enter into the testing process consciously or unconsciously. Yet some test of the model is better than none at all.

In order to introduce an element of fairness into the testing process, the results of a forecast using the model previously developed are compared not only with the actual figures for 1960 but also with the results of a "naive" model. It is felt that the ability to forecast better than the "naive" model constitutes a minimum standard of acceptability for any more complex model. As a practical matter, even if the complex model forecasts

CHAPTER VII: THE TESTING PROCESS

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Determination of Base Period Magnitudes

Tables 7.1, 7.2, 7.3, and 7.6 list the various magnitudes for 1950 estimated in the testing process. Strictly speaking, these magnitudes are assumed to be known data to the researcher. Operationally, however, data do not exist for all of the magnitudes necessary to implement the model in a concise form, and hence various estimating procedures are used. The demand for physician's services figure in Table 7.2, for example, is based upon an extrapolation of a study conducted of western Pennsylvania counties in 1950 (78, p.266). Throughout this chapter only summary tables of empirical data are presented. A detailed description of the data sources used and the assumptions necessary to use these data, as well as the procedures used to forecast the various parameters of the model, is contained in the author's doctoral dissertation, of which this report is an abstract.[1]

Public Health Service data are used for the estimates of 1950 and 1960 employment by occupation category (Tables 7.1 and 8.1) except where the

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[1]Maki, Dennis R. A forecasting model of manpower requirements in the health occupations. Unpublished Ph.D. thesis. Iowa State University, Ames, Iowa, 1967.

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1	Physicians (active, nonmilitary)	186,800[a]
2	Pharmacists	101,100
3	Chiropractors	20,000
4	Dieticians and nutritionists	22,000
5	Medical laboratory technicians and technologists	30,000
6	Medical x-ray technicians and technologists	30,800
7	Opticians lens grinders and polishers	19,200
8	Optometrists	17,800
9	Psychologists, clinical and other health	3,000
10	Occupational therapists	2,300[b]
11	Physical therapists	4,600
12	Dentists	78,917[c]
13	Dental office assistants	55,200
14	Dental hygienists	7,000
15	Dental laboratory technicians	21,000
16	Professional nurses	375,000
17	Practical nurses	137,000
18	Aides, orderlies, and attendants	221,000
19	Sanitary engineers	6,000
20	Sanitarians	5,000

Source: (107, p.14).

[a]Corrected for inactives using data in (25, p.61) and (78, p.140).

[b]Figure used is from (91, p.78).

[c]Corrected for inactives using data from (78, p.176).

data include inactives or are inconsistent with all other sources. Census data are perhaps more "reliable", but because of the highly aggregative occupation classifications employed they are not as useful for analytical purposes. The Public Health Service data (107, p.14) list employment for all occupations of interest in one summary table, leading one to expect that reasonable comparability between occupations exists.

Various sources were used in assigning personnel among the various health service categories as shown in Table 7.3. The figures in each column

Table 7.1. Estimated Employment in Selected Health Occupations in 1950

Occupation Code	Occupation Title	1950 Employment
1	Physicians (active, nonmilitary)	186,800[a]
2	Pharmacists	101,100
3	Chiropractors	20,000
4	Dieticians and nutritionists	22,000
5	Medical laboratory technicians and technologists	30,000
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Various sources were used in assigning personnel among the various health service categories as shown in Table 7.3. The figures in each column

Service Code	Service Category	Utilization (thousands)	Units
1	Short-stay hospitals	167,159	Patient-days
2	Nervous and mental hospitals	253,896	Patient-days
3	"Other" hospitals	37,862	Patient-days
4	Physicians' services	663,068	Visits
5	Dental services	194,941	Visits
6	Environmental health	150,697	Population
7	"Other health"	150,697	Population

of Table 7.3 are then divided by the corresponding number denoting total utilization of services in each category to derive the 1950 technical coefficients shown in Table 7.4. Figure 7.1 illustrates the equality $A_{50}M_{50} = X_{50}$, or stated another way, $\Sigma_k\ a_{jk}m_k = x_j$ for $j = 1, 2, \ldots 20$.

It may be noted that of the 140 technical coefficients in Table 7.4, 84 are zeros. Some of these zero coefficients are accurate. That is, the number of opticians engaged in providing dental services is probably zero. Many of the zeros are due to lack of better data, however. There are probably some dental hygienists employed in hospitals, for example, as well as some X-ray technicians in physicians' and dentists' offices. This is a handicap for accurate forecasting, but a handicap which can be at least partially overcome by judicious forecasting of changes in the technical coefficients in the case of the naive model or demand coefficients in the case of the expanded model. If suitably refined data are available and the proper degree of disaggregation of all variables is carried out, the technical and demand coefficients represent purely technical relationships. If these conditions cannot be met, the technical coefficients are affected by factors other than those affecting the production function, notably by changes in

Table 7.2. Estimated Utilization of Health Services by Category, United States, 1950

Service Code	Service Category	Utilization (thousands)	Units
1	Short-stay hospitals	167,159	Patient-days
2	Nervous and mental hospitals	253,896	Patient-days
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Table 7.3. 1950 Employment Cross-Classified by Occupation and Health Service Code

Occupation Code	Service Code 1	2	3	4	5	6	7
1	18,263	2,948	4,145	156,334	-	5,110	-
2	2,604	242	591	-	-	-	97,663
3	-	-	-	-	-	-	20,000
4	8,329	1,688	2,313	-	-	-	9,670
5	23,358	464	1,157	5,021	-	-	-
6	12,132	464	365	-	-	-	17,839
7	-	-	-	-	-	-	19,200
8	-	-	-	-	-	-	17,800
9	-	490	-	-	-	-	2,510
10	-	2,043	257	-	-	-	-
11	3,300	498	-	-	-	-	802
12	881	355	204	-	76,846	631	-
13	-	-	-	-	55,200	-	-
14	-	-	-	-	3,600	-	3,400
15	-	-	-	-	3,300	-	17,700
16	184,784	11,263	9,342	36,000	-	24,330	109,281
17	60,645	23,985	12,870	-	-	-	39,500
18	125,000	82,000	14,000	-	-	-	-
19	-	-	-	-	-	6,000	-
20	-	-	-	-	-	5,000	-

Table 7.3. 1950 Employment Cross-Classified by Occupation and Health Service Code

Occupation Code	Service Code							
	1	2	3	4	5	6	7	Total
1	18,263	2,948	4,145	156,334	-	5,110	-	186,800
2	2,604	242	591	-	-	-	97,663	101,100
3	-	-	-	-	-	-	20,000	20,000
4	8,329	1,688	2,313	-	-	-	9,670	22,000
5	23,358	464	1,157	5,021	-	-	-	30,000
6	12,132	464	365	-	-	-	17,839	30,800
7	-	-	-	-	-	-	19,200	19,200
8	-	-	-	-	-	-	17,800	17,800
9	-	490	-	-	-	-	2,510	3,000
10	-	2,043	257	-	-	-	-	2,300
11	3,300	498	-	-	-	-	802	4,600
12	881	355	204	-	76,846	631	-	78,917
13	-	-	-	-	55,200	-	-	55,200
14	-	-	-	-	3,600	-	3,400	7,000
15	-	-	-	-	3,300	-	17,700	21,000
16	184,784	11,263	9,342	36,000	-	24,330	109,281	375,000
17	60,645	23,985	12,870	-	-	-	39,500	137,000
18	125,000	82,000	14,000	-	-	-	-	221,000
19	-	-	-	-	-	6,000	-	6,000
20	-	-	-	-	-	5,000	-	5,000

between demand and actual employment by the marginal value product of the average person in the occupation. It is, of course, impossible to operationally measure the marginal value product, so it may be assumed that wage rates are approximations to the marginal value product. This is a rather heroic assumption, but since multiplying the objective function by any positive constant has no effect upon the solution values, we need only assume that <u>relative</u> wage rates are measures of relative marginal value products. This assumption is more reasonable. If we denote the relative wage rate for occupation j by r_j, our objective function becomes minimize $\Sigma_j\ r_j(x^*_{jT} - x_{jt})$.

This form still has some deficiencies, however. For an occupation which may be declining over time, i.e. one such that x^*_{jT} is less than x_{jB}, an unrealistic adjustment path is forced by the restriction $x_{jt} \leq x^*_{jT}$. Essentially the entire decrease in employment must take place in the first period rather than allowing for a gradual rate of decline. That is, x_{jB} will decline to something less than or equal to x^*_{jT} by period t = B+1. This has repercussions on other occupations as well, assuming that the total resource constraint is binding. Unrealistic adjustment paths are likely to be the result for a number of occupations.

This problem may be avoided by using a quadratic objective function and dispensing with the constraint $x_{jt} \leq x^*_{jT}$. The objective function is now of the form minimize $\Sigma_j\ [r_j\ (x^*_{jT} - x_{jt})]^2$. It is apparent that any solution in which $x_{jt} > x^*_{jT}$ is nonoptimal, since the value of the objective function is lowered by the simple expedient of reducing x_{jt} until it equals x^*_{jT}. Given the nature of the total resource constraint, this action will also free resources which can be used to hire additional personnel in other occupations where excess demand is positive, further reducing the value of the objective function. Thus with a quadratic objective function a

constraint of the form $x_{jt} \leq x^*_{jT}$ is redundant.

Still another problem exists. Assuming no difference in relative wage rates, a "shortage" of 1,000 persons in an occupation employing 5,000 persons is no more serious than a shortage of 1,000 persons in an occupation employing 500,000 workers, given the last objective function specified. This does not seem intuitively correct. One means of rectifying this is to use an objective function which minimizes squared percentage deviations. Two choices are available. One may either minimize $\Sigma_j [r_j \ (x^*_{jT} - x_{jt})/ \ x_{jt}]^2$ or $\Sigma_j [r_j \ (x^*_{jT} - x_{jt})/ \ x^*_{jT}]^2$. The former is extremely difficult to program; hence, the latter form is used in this analysis, as presented in Chapter 2. This then, is the rationalization for the form of objective function used.

It may be noted that the reasoning behind using relative wage rates as weights in the linear difference formulation is no longer as valid once we use percentage deviations. The r_j's in the linear difference form are estimates of the true weight, while using the same r_j in the percentage deviation form involves using it as a proxy for the true weight. Relative wage rates are reasonable estimates of the differences in the value to the health industry of one person in different occupations. They need not be good estimates of the difference in the value to the health industry of one percentage change in employment in different occupations. The weights are still necessary, for reasons previously stated, but it is not clear how these weights should be estimated. Relative wage rates are used in Chapter 7 as weights, but it must be realized that these are only proxies for the true weights.

Other variations of the objective function are possible. We could minimize the absolute value of the percentage deviations rather than the squared percentage deviations. The two methods would, in most cases,

yield slightly different results. The primary objection to the absolute value approach is that it is difficult to program.

Total Resource Constraint

Some form of constraint which accounts explicitly for the fact that the health industry may not be able to expand employment to the point where all "ceteris paribus demands" for individual occupations are satisfied, even abstracting from supply constraints, is an integral part of the model developed in this paper. It is assumed that there is some form of total resource constraint. This constraint states that the sum over all occupations of the product of average earnings and total employment in each occupation cannot exceed some specified figure.

The specification of the total resource constraint requires the forecasting of average earnings for each occupation and of the total amount of resources which will be available for expenditure on payroll costs. Considering average earnings first, there are several ways in which these may be estimated. If time series data are available on trends in real average earnings by occupation, we can project future earnings using regression analysis. If, at least for some occupations, we feel that dependable forecasts of exogenous variables are available, these may be utilized in forecasting future earnings. If may be anticipated that productivity will rise more rapidly in some occupations than in others, and that this will result in a more rapid increase in earnings for some occupations than others, for example. If we can estimate the magnitude of these differential rates of productivity increase, we can use these estimates to forecast earnings figures. If the seniority composition of an occupation is expected to change materially, this may affect average wage rates. In most cases,

workers with more experience earn more. If skill requirements in an occupation are expected to change, this will have an impact upon earnings. As a greater proportion of "practical nurses" become "licensed practical nurses," for example, it would be expected that average earnings in this occupation will rise. These considerations should be taken into account in forecasting earnings.

In Chapter 7 a simpler method is used. Since time series data are unavailable on earnings in most occupations, it is assumed that earnings in all occupations will change at the same rate in the future as average earnings in all manufacturing industries have changed in the past. This has some advantages in that it simplifies the computational problem. Since all earnings change at the same rate, relative earnings are constant. Thus the r_j's or weights in the objective function, are constants.

The second variable to forecast for the total resource constraint is the amount of resources available to be used to pay persons in the occupations concerned. In Chapter 7 this is estimated by forecasting net national product and total expenditures on health, both public and private, as an increasing percentage of net national product. I then assume that total earnings by persons in the occupations considered is a constant percentage of total expenditures on health. This method has some merit in that reliable outside forecasts of net national product are usually available. Expenditures on health as a percentage of net national product also appear to be a very regular function of time. The last assumption, however, is much more questionable. Even if total payroll costs were constant, this would imply that average annual earnings would be declining due to the increasing importance of fringe benefits. The Chamber of Commerce of the United States (31) reports that fringe benefits have increased from 15.5%

of total payroll in 1947 to 28% in 1963, according to a survey of 86 companies. It may be expected that many health occupations have been similarly affected. If there is any capital substitution for labor, or vice versa, this would change the percentage of total expenditures on health used to pay personnel in the occupations considered. Since we are not considering all occupations within the health industry, changes in average wage rates of occupations included in the analysis relative to those which are not included will affect the percentage of total expenditures available to pay personnel in included occupations. The assumption of constancy in this latter percentage is definitely only a rough approximation to reality. Its usefulness can be evaluated only through an analysis of the results of forecasts made using it.

A more theoretically correct approach to forecasting total expenditures on health might be to break this down by source of funds. The primary categories might be private individual consumption expenditures, governmental expenditures, expenditures by philanthropy, and expenditures of industry. We can then forecast each of these components separately, using various independent variables. Private consumption expenditures may be a function of the forecast demand for services and forecast changes in the price of services directly. Indirectly they are a function of population growth and changes in per capita real income, as well as other variables discussed in Chapter 3. Governmental expenditures may be forecast by analyzing the amounts of unexpended funds allocated to health by previous legislation, as well as the probable impact of pending and forecast future legislation. The impact of medicare and similar programs would be a factor.

Expenditures by philanthropy and industry can be estimated as functions of time. Allowance must be made for interdependencies between sources of

funds. Expenditures by philanthropy may decrease as expenditures by government, through medicare and medicaid, increase. Expenditures by business are primarily in the form of fringe benefit payments to employees, such as employer contributions to health insurance premiums. It has been estimated (58, p.43) that in 1961 employers paid 44% of all health insurance premiums. Industry also makes expenditures on health in the form of in-plant medical services for employees and provision of benefits under workmen's compensation laws. To the extent that trends in industry expenditures can be forecast by analyzing trends in benefit schedules under workmen's compensation and trends in the prevalence of hospital and medical insurance benefits negotiated through collective bargaining, these latter variables can be used to forecast industry expenditures.

Expenditures by philanthropic funds are of such diverse types as to make forecasting other than by means of a time trend very difficult. Various national voluntary agencies for the control of specific diseases are active in raising funds for health. These include organizations such as the American Cancer Society and the National Infantile Paralysis Foundation. The magnitude of funds derivable from these sources fluctuates widely from year to year, making forecasting difficult. Other magnitudes, such as the donated services of Sisters, are more stable and hence more easily forecast (58, p.57). As is true of many variables, the sum total of philanthropic expenditures appears to be a more stable function of time than is true of its individual sub-components.

There is no particular reason why a forecast of total expenditures on health made on any disaggregated basis should be more accurate than a forecast based upon an increasing percentage of net national product. The disaggregated approach would provide more information regarding how changes

are taking place, but our primary interest is not in explaining changes in expenditures. That method of forecasting expenditures which yields the most accurate information regarding labor market variables is the "best" for our purposes. The determination of this is an empirical question.

We are still left with the questionable assumption that total earnings for occupations considered is a constant percentage of total expenditures on health. This problem probably cannot be resolved unless all health occupations are included in the model. It is somewhat easier to forecast total resources available for paying personnel than to forecast total resources available for paying a selected sub-group of personnel, as historical data on total personnel costs is more easily obtainable.

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better but the cost of the information obtained is considerably greater, it may be preferable to use the more naive model. This again depends upon the use to which the results of the forecast will be put and the costs of making the "wrong" decision based upon a less accurate forecast. I allow myself the freedom to abstract from these considerations and simply compare the results of my model with those of the "naive" model with respect to accuracy of the forecast, abstracting from the costs of obtaining it.

Determination of Base Period Magnitudes

Tables 7.1, 7.2, 7.3, and 7.6 list the various magnitudes for 1950 estimated in the testing process. Strictly speaking, these magnitudes are assumed to be known data to the researcher. Operationally, however, data do not exist for all of the magnitudes necessary to implement the model in a concise form, and hence various estimating procedures are used. The demand for physician's services figure in Table 7.2, for example, is based upon an extrapolation of a study conducted of western Pennsylvania counties in 1950 (78, p.266). Throughout this chapter only summary tables of empirical data are presented. A detailed description of the data sources used and the assumptions necessary to use these data, as well as the procedures used to forecast the various parameters of the model, is contained in the author's doctoral dissertation, of which this report is an abstract.[1]

Public Health Service data are used for the estimates of 1950 and 1960 employment by occupation category (Tables 7.1 and 8.1) except where the

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[1]Maki, Dennis R. A forecasting model of manpower requirements in the health occupations. Unpublished Ph.D. thesis. Iowa State University, Ames, Iowa, 1967.

Table 7.1. Estimated Employment in Selected Health Occupations in 1950

Occupation Code	Occupation Title	1950 Employment
1	Physicians (active, nonmilitary)	186,800[a]
2	Pharmacists	101,100
3	Chiropractors	20,000
4	Dieticians and nutritionists	22,000
5	Medical laboratory technicians and technologists	30,000
6	Medical x-ray technicians and technologists	30,800
7	Opticians lens grinders and polishers	19,200
8	Optometrists	17,800
9	Psychologists, clinical and other health	3,000
10	Occupational therapists	2,300[b]
11	Physical therapists	4,600
12	Dentists	78,917[c]
13	Dental office assistants	55,200
14	Dental hygienists	7,000
15	Dental laboratory technicians	21,000
16	Professional nurses	375,000
17	Practical nurses	137,000
18	Aides, orderlies, and attendants	221,000
19	Sanitary engineers	6,000
20	Sanitarians	5,000

Source: (107, p.14).

[a]Corrected for inactives using data in (25, p.61) and (78, p.140).

[b]Figure used is from (91, p.78).

[c]Corrected for inactives using data from (78, p.176).

data include inactives or are inconsistent with all other sources. Census data are perhaps more "reliable", but because of the highly aggregative occupation classifications employed they are not as useful for analytical purposes. The Public Health Service data (107, p.14) list employment for all occupations of interest in one summary table, leading one to expect that reasonable comparability between occupations exists.

Various sources were used in assigning personnel among the various health service categories as shown in Table 7.3. The figures in each column

Table 7.2. Estimated Utilization of Health Services by Category, United States, 1950

Service Code	Service Category	Utilization (thousands)	Units
1	Short-stay hospitals	167,159	Patient-days
2	Nervous and mental hospitals	253,896	Patient-days
3	"Other" hospitals	37,862	Patient-days
4	Physicians' services	663,068	Visits
5	Dental services	194,941	Visits
6	Environmental health	150,697	Population
7	"Other health"	150,697	Population

of Table 7.3 are then divided by the corresponding number denoting total utilization of services in each category to derive the 1950 technical coefficients shown in Table 7.4. Figure 7.1 illustrates the equality $A_{50}M_{50} = X_{50}$, or stated another way, $\Sigma_k \, a_{jk}m_k = x_j$ for j = 1, 2, ... 20.

It may be noted that of the 140 technical coefficients in Table 7.4, 84 are zeros. Some of these zero coefficients are accurate. That is, the number of opticians engaged in providing dental services is probably zero. Many of the zeros are due to lack of better data, however. There are probably some dental hygienists employed in hospitals, for example, as well as some X-ray technicians in physicians' and dentists' offices. This is a handicap for accurate forecasting, but a handicap which can be at least partially overcome by judicious forecasting of changes in the technical coefficients in the case of the naive model or demand coefficients in the case of the expanded model. If suitably refined data are available and the proper degree of disaggregation of all variables is carried out, the technical and demand coefficients represent purely technical relationships. If these conditions cannot be met, the technical coefficients are affected by factors other than those affecting the production function, notably by changes in

Table 7.3. 1950 Employment Cross-Classified by Occupation and Health Service Code

Occupation Code	Service Code							
	1	2	3	4	5	6	7	Total
1	18,263	2,948	4,145	156,334	-	5,110	-	186,800
2	2,604	242	591	-	-	-	97,663	101,100
3	-	-	-	-	-	-	20,000	20,000
4	8,329	1,688	2,313	-	-	-	9,670	22,000
5	23,358	464	1,157	5,021	-	-	-	30,000
6	12,132	464	365	-	-	-	17,839	30,800
7	-	-	-	-	-	-	19,200	19,200
8	-	-	-	-	-	-	17,800	17,800
9	-	490	-	-	-	-	2,510	3,000
10	-	2,043	257	-	-	-	-	2,300
11	3,300	498	-	-	-	-	802	4,600
12	881	355	204	-	76,846	631	-	78,917
13	-	-	-	-	55,200	-	-	55,200
14	-	-	-	-	3,600	-	3,400	7,000
15	-	-	-	-	3,300	-	17,700	21,000
16	184,784	11,263	9,342	36,000	-	24,330	109,281	375,000
17	60,645	23,985	12,870	-	-	-	39,500	137,000
18	125,000	82,000	14,000	-	-	-	-	221,000
19	-	-	-	-	-	6,000	-	6,000
20	-	-	-	-	-	5,000	-	5,000

Table 7.4. Technical Coefficients for 1950

Occupation Code	Service Code						
	1	2	3	4	5	6	7
1	.1093	.0116	.1095	.2358	-	.0339	-
2	.0156	.0010	.0156	-	-	-	.6481
3	-	-	-	-	-	-	.1327
4	.0498	.0066	.0611	-	-	-	.0642
5	.1397	.0018	.0306	.0076	-	-	-
6	.0726	.0018	.0096	-	-	-	.1184
7	-	-	-	-	-	-	.1274
8	-	-	-	-	-	-	.1181
9	-	.0019	-	-	-	-	.0167
10	-	.0080	.0068	-	-	-	-
11	.0197	.0020	-	-	-	-	.0053
12	.0053	.0014	.0054	-	.3942	.0042	-
13	-	-	-	-	.2832	-	-
14	-	-	-	-	.0185	-	.0226
15	-	-	-	-	.0169	-	.1175
16	1.1054	.0444	.2467	.0543	-	.1614	.7252
17	.3628	.0945	.3399	-	-	-	.2621
18	.7478	.3230	.3698	-	-	-	-
19	-	-	-	-	-	.0398	-
20	-	-	-	-	-	.0332	-

$$
\begin{bmatrix}
.1093 & .0116 & .1095 & .2358 & - & .0339 & - \\
.0156 & .0010 & .0156 & - & - & - & .6481 \\
- & - & - & - & - & - & .1327 \\
.0498 & .0066 & .0611 & - & - & - & .0642 \\
.1397 & .0018 & .0306 & .0076 & - & - & - \\
.0726 & .0018 & .0096 & - & - & - & .1184 \\
- & - & - & - & - & - & .1274 \\
- & - & - & - & - & - & .1181 \\
- & .0019 & - & - & - & - & .0167 \\
- & .0080 & .0068 & - & - & - & - \\
.0197 & .0020 & - & - & - & - & .0053 \\
.0053 & .0014 & .0054 & - & .3942 & .0042 & - \\
- & - & - & - & .2832 & - & - \\
- & - & - & - & .0185 & - & .0226 \\
- & - & - & - & .0169 & - & .1175 \\
1.1054 & .0444 & .2467 & .0543 & - & .1614 & .7252 \\
.3628 & .0945 & .3399 & - & - & - & .2621 \\
.7478 & .3230 & .3698 & - & - & - & - \\
- & - & - & - & - & .0398 & - \\
- & - & - & - & - & .0332 & -
\end{bmatrix}
\times
\begin{bmatrix}
167{,}159 \\ 253{,}896 \\ 37{,}862 \\ 663{,}068 \\ 194{,}941 \\ 150{,}697 \\ 150{,}697
\end{bmatrix}
=
\begin{bmatrix}
186{,}800 \\ 101{,}100 \\ 20{,}000 \\ 22{,}000 \\ 30{,}000 \\ 30{,}800 \\ 19{,}200 \\ 17{,}800 \\ 3{,}000 \\ 2{,}300 \\ 4{,}600 \\ 78{,}917 \\ 55{,}200 \\ 7{,}000 \\ 21{,}000 \\ 375{,}000 \\ 137{,}000 \\ 221{,}000 \\ 6{,}000 \\ 5{,}000
\end{bmatrix}
$$

Fig. 7.1. $A_{50}\ M_{50} = X_{50}$.

demand characteristics.

In Table 7.3 we have data on employment by occupation and health service category, or x_{jk50}. We now need data on excess demand, or y_{jk50}, which can then be added to x_{jk50} to get total demand, denoted x^*_{jk50}. It is not really necessary to disaggregate total demand for personnel by health service category, as the recursive program uses only x^*_{j60}. It is in my thesis, however, that increased accuracy is gained by forecasting a^*_{jk60} and m_{k60} separately and then computing $\Sigma_k\ a^*_{jk60}m_{k60}$ to obtain x^*_{j60}.

The estimates of y_{jk50} are contained in Table 7.6. In most cases data on budgeted vacancies were used to derive these estimates, which were first expressed as percentages of employment in 1950 (Table 7.5) and then converted to an absolute basis. For physicians and dentists, the majority of whom are self-employed, the concept of budgeted vacancies is not meaningful. For these occupations an analysis of rates of return to investment in training as computed by W. Lee Hansen (53) was used as the basis for the excess demand estimate. An estimate was made of the number of persons in each occupation which, had they been employed, would have reduced the rate of return to investment in training for physicians and dentists to the rate of return for male college graduates as a whole. The difference between this figure and actual employment is then considered to be excess demand.

If any technical coefficient was estimated to be zero, the corresponding demand coefficient was also constrained to be zero. This provides a measure of comparability between the two figures.

Adding the corresponding figures from Tables 7.3 and 7.6 yields the estimates of total demand shown in Table 7.7. Dividing the numbers in each column of this table by the estimated utilization of services in each health service category (Table 7.2) yields the demand coefficients listed in Table 7.8. Figure 7.2 illustrates the equality $A^*_{50}M_{50} = X^*_{50}$.

Table 7.5. Excess Demand as a Percentage of Employment, Cross-Classified by Occupation and Health Service Category, 1950

Occupation	Service Code							
Code	1	2	3	4	5	6	7	Total
1	31.0	31.5	31.8	20.8	-	0.0	-	21.6
2	14.0	14.0	14.0	-	-	-	0.0	0.5
3	-	-	-	-	-	-	0.0	0.0
4	32.5	32.5	32.5	-	-	-	0.0	18.2
5	15.0	15.1	15.0	15.0	-	-	-	15.0
6	16.4	16.4	16.4	-	-	-	16.4	16.4
7	-	-	-	-	-	-	0.0	0.0
8	-	-	-	-	-	-	0.0	0.0
9	-	21.0	-	-	-	-	150.0	128.9
10	-	62.5	62.5	-	-	-	-	62.5
11	37.2	37.1	-	-	-	-	0.0	30.7
12	24.9	25.1	25.0	-	14.4	0.0	-	14.4
13	-	-	-	-	0.0	-	-	0.0
14	-	-	-	-	0.0	-	13.2	6.4
15	-	-	-	-	0.0	-	0.0	0.0
16	9.0	20.1	9.0	9.0	-	9.0	9.0	9.3
17	38.0	38.0	38.0	-	-	-	38.0	38.0
18	13.6	5.8	21.0	-	-	-	-	11.2
19	-	-	-	-	-	17.0	-	17.0
20	-	-	-	-	-	5.9	-	5.9

Source: Computed from Tables 7.3 and 7.6.

Table 7.6. Excess Demand in 1950 Cross-Classified by Occupation and Health Service Category

Occupation Code	Service Code 1	2	3	4	5	6	7	Total
1	5,662	928	1,285	32,510	-	-	-	40,385
2	365	34	83	-	-	-	-	482
3	-	-	-	-	-	-	-	-
4	2,707	549	752	-	-	-	-	4,008
5	3,504	70	174	753	-	-	-	4,501
6	1,990	76	60	-	-	-	2,926	5,052
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	103	-	-	-	-	3,765	3,868
10	-	1,277	161	-	-	-	-	1,438
11	1,228	185	-	-	-	-	-	1,413
12	220	89	51	-	11,035	-	-	11,395
13	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	450	450
15	-	-	-	-	-	-	-	-
16	16,631	2,262	841	3,240	-	2,190	9,835	34,999
17	23,045	9,114	4,891	-	-	-	15,010	52,060
18	17,030	4,756	2,940	-	-	-	-	24,726
19	-	-	-	-	-	1,020	-	1,020
20	-	-	-	-	-	295	-	295

Table 7.7. Total Demand in 1950 Cross-Classified by Occupation and Health Service Category

Occupation Code	Service Code							
	1	2	3	4	5	6	7	Total
1	23,925	3,876	5,430	188,844	-	5,110	-	227,185
2	2,969	276	674	-	-	-	97,663	101,582
3	-	-	-	-	-	-	20,000	20,000
4	11,036	2,237	3,065	-	-	-	9,670	26,008
5	26,862	534	1,331	5,874	-	-	-	34,501
6	14,122	540	425	-	-	-	20,765	35,852
7	-	-	-	-	-	-	19,200	19,200
8	-	-	-	-	-	-	17,800	17,800
9	-	593	-	-	-	-	6,275	6,868
10	-	3,320	418	-	-	-	-	3,738
11	4,528	683	-	-	-	-	802	6,013
12	1,101	444	255	-	87,881	631	-	90,312
13	-	-	-	-	55,200	-	-	55,200
14	-	-	-	-	3,600	-	3,850	7,450
15	-	-	-	-	3,300	-	17,700	21,000
16	201,415	13,525	10,183	39,240	-	26,520	119,116	409,999
17	83,690	33,099	17,761	-	-	-	54,510	189,060
18	142,030	86,756	16,940	-	-	-	-	245,726
19	-	-	-	-	-	7,020	-	7,020
20	-	-	-	-	-	5,295	-	5,295

Table 7.8. Demand Coefficients for 1950

Occupation Code	Service Code 1	2	3	4	5	6	7
1	.1431	.0153	.1434	.2848	-	.0339	-
2	.0178	.0011	.0178	-	-	-	.6481
3	-	-	-	-	-	-	.1327
4	.0660	.0088	.0810	-	-	-	.0642
5	.1607	.0021	.0352	.0089	-	-	-
6	.0845	.0021	.0112	-	-	-	.1378
7	-	-	-	-	-	-	.1274
8	-	-	-	-	-	-	.1181
9	-	.0023	-	-	-	-	.0416
10	-	.0131	.0110	-	-	-	-
11	.0271	.0027	-	-	-	-	.0053
12	.0066	.0017	.0067	-	.4508	.0042	-
13	-	-	-	-	.2832	-	-
14	-	-	-	-	.0185	-	.0255
15	-	-	-	-	.0169	-	.1175
16	1.2049	.0532	.2690	.0592	-	.1760	.7904
17	.5007	.1304	.4691	-	-	-	.3617
18	.8497	.3417	.4474	-	-	-	-
19	-	-	-	-	-	.0466	-
20	-	-	-	-	-	.0351	-

$$
\begin{bmatrix}
.1431 & .0153 & .1434 & .2848 & - & .0339 & - \\
.0178 & .0011 & .0178 & - & - & - & .6481 \\
- & - & - & - & - & - & .1327 \\
.0660 & .0088 & .0810 & - & - & - & .0642 \\
.1607 & .0021 & .0352 & .0089 & - & - & - \\
.0845 & .0021 & .0112 & - & - & - & .1378 \\
- & - & - & - & - & - & .1274 \\
- & - & - & - & - & - & .1181 \\
- & .0023 & - & - & - & - & .0416 \\
- & .0131 & .0110 & - & - & - & - \\
.0271 & .0027 & - & - & - & - & .0053 \\
.0066 & .0017 & .0067 & - & .4508 & .0042 & - \\
- & - & - & - & .2832 & - & - \\
- & - & - & - & .0185 & - & .0255 \\
- & - & - & - & .0169 & - & .1175 \\
1.2049 & .0532 & .2690 & .0592 & - & .1760 & .7904 \\
.5007 & .1304 & .4691 & - & - & - & .3617 \\
.8497 & .3417 & .4474 & - & - & - & - \\
- & - & - & - & - & .0466 & - \\
- & - & - & - & - & .0351 & -
\end{bmatrix}
\times
\begin{bmatrix}
167{,}159 \\ 253{,}896 \\ 37{,}862 \\ 663{,}068 \\ 194{,}941 \\ 150{,}697 \\ 150{,}697
\end{bmatrix}
=
\begin{bmatrix}
227{,}185 \\ 101{,}582 \\ 20{,}000 \\ 26{,}008 \\ 34{,}501 \\ 35{,}852 \\ 19{,}200 \\ 17{,}800 \\ 6{,}868 \\ 3{,}738 \\ 6{,}013 \\ 90{,}312 \\ 55{,}200 \\ 7{,}450 \\ 21{,}000 \\ 409{,}999 \\ 189{,}060 \\ 245{,}726 \\ 7{,}020 \\ 5{,}295
\end{bmatrix}
$$

Fig. 7.2. $A^*_{50}\ M_{50} = X^*_{50}$.

Estimation of Target Year Service Utilization

Actual data on the utilization of the various categories of health services were utilized in the testing process, rather than attempting to forecast these magnitudes. Thus the only portion of the model being tested herein is the conversion of estimates of the demand for services into a forecast of requirements for personnel. The figures on 1960 utilization of services shown in Table 7.9 are not strictly comparable to the 1950 magnitudes listed in Table 7.2 as it was necessary to use different sources for the two periods. The hospital data for 1950 are based upon the American Medical Association annual surveys, which were not conducted after 1955. The 1960 data are based upon the American Hospital Association annual survey (7, pp. 414-15). Information of the differences between the two reporting systems is contained in Bachman (25, p.117).

Table 7.9. Estimated Utilization of Health Services by Category, United States, 1960

Service Code	Service Title	Utilization (thousands)	Units	Percent Change 1950 - 1960, Annual Rate
1	Short-stay hospitals	203,481	Patient-days	2.17
2	Nervous and mental hospitals	269,555	Patient-days	0.62
3	"Other" hospitals	39,045	Patient-days	0.31
4	Physicians' services outside hospitals	839,026	Visits	2.65
5	Dental services	275,454	Visits	4.13
6	Environmental health	179,323	Persons	1.90
7	"Other health" services	179,323	Persons	1.90

Forecasting Technical Coefficients for 1960

The naive model is implemented by forecasting the elements of a matrix A_{60} using A_{50} and any other information available in 1950 which may be deemed to be relevant. The forecasting process was constrained by assuming that any a_{jk} which was zero in 1950 would also be zero in 1960. Most of the coefficients were forecast by computing a regression of values of the technical coefficient in some base period on time and then using this regression equation to forecast the 1960 value of that coefficient. Nonlinear trends were assumed in some cases.

No change was forecast for several coefficients over the 1950-1960 period. This may be because no information was available to use as a basis for forecasting or because such qualitative information as was available indicated that any changes would be minor. The details of the forecasting procedure for each individual coefficient are contained in the author's doctoral dissertation, previously cited.

For some coefficients independent variables other than time were utilized. Changes in the technical coefficients for self-employed physicians and dentists were forecast based upon trends in productivity, using data in Tables 4.4 and 4.5 respectively. Data for the war years, 1941-1945, were excluded from the base used in computing the trend because of the nontypical nature of the data in this period.

Table 7.10 summarizes the forecast technical coefficients for 1960. There are converted to forecast employment figures cross-classified by occupation and health service code in Table 7.11. Table 7.12 details the percentage increase in forecast employment over the 1950-1960 period. Finally, Fig. 7.3 illustrates the equality $A_{60}M_{60} = X_{60}$, written in matrix

Table 7.10. Forecast Technical Coefficients for 1960

Occupation Code	Service Code 1	2	3	4	5	6	7
1	.1249	.0174	.1252	.2054	-	.0339	-
2	.0156	.0011	.0156	-	-	-	.6384
3	-	-	-	-	-	-	.1385
4	.0498	.0066	.0611	-	-	-	.0642
5	.2210	.0021	.0484	.0120	-	-	-
6	.1556	.0021	.0150	-	-	-	.2196
7	-	-	-	-	-	-	.1222
8	-	-	-	-	-	-	.1036
9	-	.0050	-	-	-	-	.0262
10	-	.0187	.0068	-	-	-	-
11	.0363	.0037	-	-	-	-	.0053
12	.0053	.0016	.0054	-	.2957	.0042	-
13	-	-	-	-	.3027	-	-
14	-	-	-	-	.0185	-	.0381
15	-	-	-	-	.0169	-	.1175
16	1.4348	.0542	.2807	.0543	-	.2085	.7252
17	.4473	.1132	.4123	-	-	-	.2621
18	1.5293	.3983	.4049	-	-	-	-
19	-	-	-	-	-	.0597	-
20	-	-	-	-	-	.0503	-

Table 7.11. Employment Cross-Classified by Occupation and Service Category as Forecast for 1960 Using the Naive Model

Occupation	Service Code							
Code	1	2	3	4	5	6	7	Total
1	25,415	4,690	4,888	172,336	-	6,079	-	213,408
2	3,174	297	609	-	-	-	114,480	118,560
3	-	-	-	-	-	-	24,836	24,836
4	10,133	1,779	2,386	-	-	-	11,513	25,811
5	44,969	566	1,890	10,068	-	-	-	57,493
6	31,662	566	586	-	-	-	39,379	72,193
7	-	-	-	-	-	-	21,913	21,913
8	-	-	-	-	-	-	18,578	18,578
9	-	1,348	-	-	-	-	4,698	6,046
10	-	5,041	266	-	-	-	-	5,307
11	7,386	997	-	-	-	-	950	9,333
12	1,078	431	211	-	81,452	753	-	83,925
13	-	-	-	-	83,380	-	-	83,380
14	-	-	-	-	5,096	-	6,832	11,928
15	-	-	-	-	4,655	-	21,070	25,725
16	291,955	14,610	10,960	45,559	-	37,389	130,045	530,518
17	91,017	30,514	16,098	-	-	-	47,001	184,630
18	311,183	107,364	15,809	-	-	-	-	434,356
19	-	-	-	-	-	10,706	-	10,706
20	-	-	-	-	-	9,020	-	9,020

Table 7.12. Percentage Increase in Employment, 1960 Forecast by Naive Model Over 1950 Actual, Cross-Classified by Occupation and Service Category

Occupation Code	Service Code 1	2	3	4	5	6	7	Total
1	39.2	59.1	17.9	10.2	-	19.0	-	14.2
2	21.9	22.7	3.0	-	-	-	17.2	17.3
3	-	-	-	-	-	-	24.2	24.2
4	21.7	5.4	3.2	-	-	-	19.1	17.3
5	92.5	22.0	63.4	100.5	-	-	-	91.6
6	161.0	22.0	60.5	-	-	-	120.7	134.4
7	-	-	-	-	-	-	14.1	14.1
8	-	-	-	-	-	-	4.4	4.4
9	-	175.1	-	-	-	-	87.2	101.5
10	-	146.7	3.5	-	-	-	-	130.7
11	123.8	100.2	-	-	-	-	18.5	102.9
12	22.4	21.4	3.4	-	6.0	19.3	-	6.3
13	-	-	-	-	51.1	-	-	51.1
14	-	-	-	-	41.6	-	100.9	70.4
15	-	-	-	-	41.1	-	19.0	22.5
16	58.0	29.7	17.3	26.6	-	53.7	19.0	41.5
17	61.3	27.2	25.1	-	-	-	19.0	34.8
18	148.9	30.9	12.9	-	-	-	-	96.5
19	-	-	-	-	-	78.4	-	78.4
20	-	-	-	-	-	80.4	-	80.4

$$
\begin{bmatrix}
.1249 & .0174 & .1252 & .2054 & - & .0339 & - \\
.0156 & .0011 & .0156 & - & - & - & .6384 \\
- & - & - & - & - & - & .1385 \\
.0498 & .0066 & .0611 & - & - & - & .0642 \\
.2210 & .0021 & .0484 & .0120 & - & - & - \\
.1556 & .0021 & .0150 & - & - & - & .2196 \\
- & - & - & - & - & - & .1222 \\
- & - & - & - & - & - & .1036 \\
- & .0050 & - & - & - & - & .0262 \\
- & .0187 & .0068 & - & - & - & - \\
.0363 & .0037 & - & - & - & - & .0053 \\
.0053 & .0016 & .0054 & - & .2957 & .0042 & - \\
- & - & - & - & .3027 & - & - \\
- & - & - & - & .0185 & - & .0381 \\
- & - & - & - & .0169 & - & .1175 \\
1.4348 & .0542 & .2807 & .0543 & - & .2085 & .7252 \\
.4473 & .1132 & .4123 & - & - & - & .2621 \\
1.5293 & .3983 & .4049 & - & - & - & - \\
- & - & - & - & - & .0597 & - \\
- & - & - & - & - & .0503 & -
\end{bmatrix}
\times
\begin{bmatrix}
203,481 \\ 269,555 \\ 39,045 \\ 839,026 \\ 275,454 \\ 179,323 \\ 179,323
\end{bmatrix}
=
\begin{bmatrix}
213,408 \\ 118,560 \\ 24,836 \\ 25,811 \\ 57,493 \\ 72,193 \\ 21,913 \\ 18,578 \\ 6,046 \\ 5,307 \\ 9,333 \\ 83,925 \\ 83,380 \\ 11,928 \\ 25,725 \\ 530,518 \\ 184,630 \\ 434,356 \\ 10,706 \\ 9,020
\end{bmatrix}
$$

Fig. 7.3. $A_{60}\ M_{60} = X_{60}$.

notation. It is understood that the elements of A_{60}, and hence of X_{60}, are forecast magnitudes.

Forecasting Demand Coefficients for 1960

There are numerous methods which could be used to forecast changes in the demand coefficients. The most straightforward method might be to derive a time series of values of demand coefficients for some number of years prior to 1950 and then compute a regression of these values on time. This requires time series data on excess demand, or budgeted vacancies, which exist for very few occupation service categories considered in this study. This makes it very difficult to forecast changes in the demand coefficients. On the other hand, it is more reasonable to assume that demand coefficients will change slowly over time than it is to make the same assumption regarding technical coefficients. Technical coefficients are affected by changes in supply as well as changes in the production function, while demand coefficients are functions of the latter only. For this reason as well as the lack of data, a large number of demand coefficients are assumed unchanged over the 1950 - 1960 period.

Information uncovered in the process of forecasting the technical coefficients for 1960 in the previous section is useful in this section as well. For those occupation service categories where no excess demand was estimated in 1950, it is reasonable to assume that forecast changes in the demand coefficients will be the same as forecast changes in the technical coefficients, providing that I did not explicitly incorporate supply considerations into my forecast of the technical coefficients. Also, if any forecast technical coefficient for 1960 is greater than the forecast demand coefficient for that same year, one forecast or the other must be inaccurate. Employment trends alone are not sufficient to forecast demand, but employment cannot

exceed demand. In forecasting demand coefficients for 1960, if assuming the 1950 demand coefficient unchanged results in a magnitude smaller than the forecast 1960 technical coefficient shown in Table 7.10, the latter is used as the forecast 1960 demand coefficient as well. This probably has the effect of giving the forecast 1960 demand coefficients a conservative bias.

Time series data on budgeted vacancies are available for persons employed in health service code 2, nervous and mental hospitals. This was used as the basis of demand coefficient forecasts for these categories. The demand coefficients for the other service categories were forecast using the relationships between the 1950 technical and demand coefficients and the forecast 1960 technical coefficients, as previously outlined.

Table 7.13 lists the resulting forecast demand coefficients for 1960. These are converted into absolute figures in Table 7.14. Table 7.15 lists the percentage increase in total demand over the 1950 - 1960 period. Figure 7.4 illustrates the equality $A^*_{60}M_{60} = X^*_{60}$. Note that the only part of the information contained in these tables actually used by the recursive program is the last column in Table 7.14, i.e. total demand in 1960.

Derivation of Constraints for Program

The recursive program introduces the supply of personnel through the use of constraints of the form $x_{jt} \leq (1 + B_{j,max,t})\, x_{j,t-1}$. The $B_{j,max,t}$ represents the maximum percentage increase possible in the supply of workers in occupation j in time period t. The notation x_{jB} is used herein as actual employment of workers in the base period and not necessarily supply of workers in case supply exceeds demand. The assumption is equivalent to stating that for no occupation was excess demand negative in the base period, i.e. 1950. Further, I assume that real wages do not change for

Table 7.13. Forecast Demand Coefficients, 1960

Occupation Code	Service Code						
	1	2	3	4	5	6	7
1	.1431	.0259	.1434	.2848	-	.0339	-
2	.0178	.0016	.0178	-	-	-	.6384
3	-	-	-	-	-	-	.1385
4	.0660	.0088	.0810	-	-	-	.0642
5	.2210	.0042	.0484	.0120	-	-	-
6	.1556	.0042	.0150	-	-	-	.2196
7	-	-	-	-	-	-	.1222
8	-	-	-	-	-	-	.1036
9	-	.0058	-	-	-	-	.0416
10	-	.0254	.0110	-	-	-	-
11	.0363	.0055	-	-	-	-	.0053
12	.0066	.0025	.0067	-	.4508	.0042	-
13	-	-	-	-	.3027	-	-
14	-	-	-	-	.0185	-	.0381
15	-	-	-	-	.0169	-	.1175
16	1.4348	.0887	.2807	.0592	-	.2085	.7904
17	.5007	.2145	.4691	-	-	-	.3617
18	1.5293	.5621	.4474	-	-	-	-
19	-	-	-	-	-	.0597	-
20	-	-	-	-	-	.0503	-

Table 7.14. Total Demand in 1960 as Forecast, Cross-Classified by Occupation and Health Service Code

Occupation Code	Service Code							
	1	2	3	4	5	6	7	Total
1	29,118	6,981	5,599	238,955	-	6,079	-	286,732
2	3,622	431	695	-	-	-	114,480	119,228
3	-	-	-	-	-	-	24,836	24,836
4	13,430	2,372	3,163	-	-	-	11,512	30,477
5	44,969	1,132	1,890	10,069	-	-	-	58,060
6	31,662	1,132	586	-	-	-	39,379	72,759
7	-	-	-	-	-	-	21,913	21,913
8	-	-	-	-	-	-	18,578	18,578
9	-	1,563	-	-	-	-	7,460	9,023
10	-	6,847	429	-	-	-	-	7,276
11	7,386	1,483	-	-	-	-	950	9,819
12	1,343	674	262	-	124,174	753	-	127,206
13	-	-	-	-	83,380	-	-	83,380
14	-	-	-	-	5,096	-	6,832	11,928
15	-	-	-	-	4,655	-	21,071	25,726
16	291,955	23,910	10,960	49,670	-	37,389	141,736	555,620
17	101,883	57,820	18,316	-	-	-	64,861	242,880
18	311,183	151,517	17,469	-	-	-	-	480,169
19	-	-	-	-	-	10,706	-	10,706
20	-	-	-	-	-	9,020	-	9,020

Table 7.15. Percentage Change in Demand, 1950 to 1960, Cross-Classified by Occupation and Health Service Code

Occupation	Service Code							
Code	1	2	3	4	5	6	7	Total
1	21.7	80.1	3.1	26.5	-	19.0	-	26.2
2	22.0	56.2	3.1	-	-	-	17.2	17.4
3	-	-	-	-	-	-	24.2	24.2
4	21.7	6.0	3.2	-	-	-	19.0	17.2
5	67.4	112.0	42.0	71.4	-	-	-	68.3
6	124.2	109.6	37.9	-	-	-	89.6	102.9
7	-	-	-	-	-	-	14.1	14.1
8	-	-	-	-	-	-	4.4	4.4
9	-	163.6	-	-	-	-	18.9	31.4
10	-	106.2	2.6	-	-	-	-	94.6
11	63.1	117.1	-	-	-	-	18.5	63.3
12	22.0	51.8	2.7	-	41.3	19.3	-	40.9
13	-	-	-	-	51.1	-	-	51.1
14	-	-	-	-	41.6	-	77.5	60.1
15	-	-	-	-	41.1	-	19.0	22.5
16	45.0	76.8	7.6	26.6	-	41.0	19.0	35.5
17	21.7	74.7	3.1	-	-	-	19.0	28.5
18	119.1	74.6	3.1	-	-	-	-	95.4
19	-	-	-	-	-	52.5	-	52.5
20	-	-	-	-	-	70.3	-	70.3

$$\begin{bmatrix}
.1431 & .0259 & .1434 & .2848 & - & .0339 & - \\
.0178 & .0016 & .0178 & - & - & - & .6384 \\
- & - & - & - & - & - & .1385 \\
.0660 & .0088 & .0810 & - & - & - & .0642 \\
.2210 & .0042 & .0484 & .0120 & - & - & - \\
.1556 & .0042 & .0150 & - & - & - & .2196 \\
- & - & - & - & - & - & .1222 \\
- & - & - & - & - & - & .1036 \\
- & .0058 & - & - & - & - & .0416 \\
- & .0254 & .0110 & - & - & - & - \\
.0363 & .0055 & - & - & - & - & .0053 \\
.0066 & .0025 & .0067 & - & .4508 & .0042 & - \\
- & - & - & - & .3027 & - & - \\
- & - & - & - & .0185 & - & .0381 \\
- & - & - & - & .0169 & - & .1175 \\
1.4348 & .0887 & .2807 & .0592 & - & .2085 & .7904 \\
.5007 & .2145 & .4691 & - & - & - & .3617 \\
1.5293 & .5621 & .4474 & - & - & - & - \\
- & - & - & - & - & .0597 & - \\
- & - & - & - & - & .0503 & -
\end{bmatrix}
\begin{bmatrix}
203{,}481 \\ 269{,}555 \\ 39{,}045 \\ 839{,}026 \\ 275{,}454 \\ 179{,}323 \\ 179{,}323
\end{bmatrix}
=
\begin{bmatrix}
286{,}732 \\ 119{,}228 \\ 24{,}836 \\ 30{,}477 \\ 58{,}060 \\ 72{,}759 \\ 21{,}913 \\ 18{,}578 \\ 9{,}023 \\ 7{,}276 \\ 9{,}819 \\ 127{,}206 \\ 83{,}380 \\ 11{,}928 \\ 25{,}726 \\ 555{,}620 \\ 242{,}880 \\ 480{,}169 \\ 10{,}706 \\ 9{,}020
\end{bmatrix}$$

Fig. 7.4. $A^*_{60}\ M_{60} = X^*_{60}$.

any occupation relative to any other over the forecast period, or that if they do this elicits no supply response due to inactive trained personnel reentering the labor market. Given this, the $B_{j,max,t}$ is a function only of the rate at which persons in occupation j leave the labor force (due to deaths, retirements, changing occupations, or withdrawal for other reasons) and the output of training institutions. Note that these assumptions are made herein only to simplify the estimation of the $B_{j,max,t}$. The model in its full generality is not constrained to adhere to these assumptions.

For some occupations, a lower bound constraint of the form $x_{jt} \geq (1 - B_{j,min,t})\ x_{j,t-1}$ was estimated. Here $B_{j,min,t}$ is the maximum percentage decrease possible in the supply of personnel in occupation j in time period t. This constraint is truly operative only in the case of self-employed persons. This type of constraint is estimated herein only for those occupations in which most of the persons employed are in the self-employed category. If the health industry were to find it propitious to decrease the number of dental office assistants employed, for example, there is no reason this could not be reduced to zero. Non-negativity constraints are inserted into the program for occupations having no other lower bound constraint.

We may define a net incremental addition to the supply of personnel in occupation j, denoted S_{jt}, as the difference between the number of trained personnel added to potential employment in occupation j minus persons leaving potential employment in occupation j for various reasons. Note that the S_{jt} are unrestricted as to sign. To clear up the notation, since S_{jt} is really a flow concept and not a stock concept, S_{jt} is used herein to denote the net incremental addition to supply in occupation j between time t-1 and time t. It is then obvious that $B_{j,max,t} = S_{jt}/x_{jt-1}$. Our

purpose in this section is to estimate S_{jt} for the twenty occupations considered for the years 1951 through 1960. For most occupations, this is accomplished by finding a function of the form $S_{jt}(t = 1951, 1952, \ldots 1960) = f\ [S_{jt}(t = 1950, 1949 \ldots, 1945)]$. Note again that the S_{jt} need not be forecast in this manner. The model in its full generality allows any variables which may be useful to serve as independent variables in the forecasting of S_{jt} for years subsequent to $t = B$.

In most instances it is easiest to forecast gross additions to an occupation, denoted G_{jt}, in terms of numbers of personnel, and to forecast deletions, usually in the form of deaths, as a percentage figure. This percentage is denoted d_{jt}. For these occupations $S_{jt} = G_{jt} - d_{jt}X_{jt-1}$, or $B_{j,max,t} = G_{jt}/X_{jt-1} - d_{jt}$.

Various techniques were used to forecast d_{jt} and G_{jt} in this analysis. The final results of the process are summarized in Figures 7.5 - 7.14. For occupation codes 7, 13, 16, 17, and 18 a different method is utilized. The supply constraint for occupation code 16, professional nurses, is forecast using the series on the percentage of nurses active by number of years since graduation developed by Margaret West (137, p.657). Considering the above series as a vector of constants, supply is forecast by taking successive dot products of this vector and a vector composed of the number of nursing graduates. Nursing graduates for the period 1951 - 1960 are, of course, forecast values. The supply constraint for the remaining four occupation codes are estimated simply by forcing a linear adjustment path between 1950 employment and 1960 "ceteris paribus" demand, as forecast. For these occupations, $B_{j,max,t}$ is estimated as $(x^*_{j60} - x_{j50})/10\ x_{j,t-1}$. The rationale for this procedure is that training requirements for entry into these occupations are minimal, and the supply constraint should not be binding. A

constraint is necessary to prevent unrealistic repercussions on other occupation categories caused by a binding total resource constraint.

In order to estimate the coefficients for the total resource constraint, it is necessary to obtain estimates of average annual earnings for all occupations in 1950 and then to project these figures to 1960. The 1950 data are listed in Table 7.16. No data are available regarding trends in average earnings for the occupations in question, so the trend in average weekly gross earnings in the manufacturing industries was used in forecasting. This same rate of increase was assumed to apply to all occupation categories considered in this study, resulting in the figures shown in Table 7.17. The error introduced by this obviously unrealistic assumption may not be large as long as the average increase in average annual earnings is forecast reasonably accurately. The program is not very sensitive to small changes in the average annual earnings figures for individual occupations. The assumption of the same rate of increase for all occupations somewhat simplifies the computations involved in solving the quadratic program in that since relative earnings are unchanged, the same objective function parameters are applicable for all time periods.

The relative average annual earnings figures in Table 7.16 are used herein as estimates of the r_j. The rationalization for this is that it is assumed that relative average annual earnings are a proxy for relative marginal revenue products.

TR_t was estimated as follows. First, total payroll expenditures for the twenty occupation categories considered as a percentage of total expenditures on health in 1950 was computed to be 37.96%. This percentage was assumed to be constant over the 1950 - 1960 period. This assumption is unsubstantiated by any evidence regarding its reality. Then a forecast

Table 7.16. Average Annual Earnings in 1950 by Occupation Code, and Relative Average Annual Earnings[a]

Occupation Code	Average Annual Earnings	Relative	Occupation Code	Average Annual Earnings	Relative
1	8,669	546	11	3,111	196
2	4,363	275	12	6,820	430
3	3,437	217	13	1,699	107
4	2,202	139	14	2,500	158
5	3,626	228	15	3,293	207
6	2,941	185	16	2,313	146
7	3,259	205	17	1,735	109
8	4,563	288	18	1,587	100
9	4,524	285	19	4,300	271
10	3,042	192	20	3,200	202

Source: (95, pp. 183, 186, 189, 191, 194, and 197), (91, pp. 62, 73, 153, 237, and 110), (132, p.33), (133, p.16), (79, pp. 258 and 259).

[a]Note: Since data were primarily for 1949, 1950 estimates are obtained by deflating by an index of average gross weekly earnings in manufacturing, 1950 = 100 (38, p.226). This is an index of earnings in current prices.

was made of net national product for each year from 1951 to 1960, expressed as a linear function of time. The resulting equation is NNP = 124.99 + 9.22t, expressed in billions of dollars. Time is coded 1936 = 1. Total expenditures on health was then forecast as an increasing percentage of net national product. The equation for this relationship is (100) (EOH) /NNP = 3.2158 + /1096t, where time is again coded 1936 = 1. Taking the product of these three magnitudes for successive years yields the forecasts of TR_t, shown in Figures 7.5 through 7.14.

Generation of Employment Forecast Using Recursive Program

All of the parameters required to make the recursive program described in Chapter 2 operative have now been estimated. The programs for each of the ten years, 1951 - 1960, are shown in the following Figures. The solution

Table 7.17. Forecast Average Annual Earnings by Occupation, 1951 - 1960, in Constant 1950 Dollars

Occupation Code	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
1	8,899	9,128	9,358	9,588	9,818	10,047	10,277	10,507	10,737	10,966
2	4,479	4,594	4,710	4,825	4,941	5,057	5,172	5,288	5,404	5,519
3	3,528	3,619	3,710	3,801	3,892	3,983	4,075	4,166	4,257	4,348
4	2,260	2,319	2,377	2,435	2,494	2,552	2,610	2,669	2,727	2,786
5	3,722	3,818	3,914	4,010	4,106	4,203	4,299	4,395	4,491	4,587
6	3,019	3,097	3,175	3,253	3,331	3,409	3,487	3,564	3,642	3,720
7	3,345	3,432	3,518	3,604	3,691	3,777	3,864	3,950	4,036	4,123
8	4,684	4,805	4,926	5,047	5,168	5,289	5,409	5,530	5,651	5,772
9	4,644	4,764	4,884	5,004	5,123	5,243	5,363	5,483	5,603	5,723
10	3,123	3,203	3,284	3,364	3,445	3,526	3,606	3,687	3,768	3,848
11	3,193	3,276	3,358	3,441	3,523	3,606	3,688	3,771	3,853	3,935
12	7,001	7,181	7,362	7,543	7,724	7,904	8,085	8,266	8,447	8,627
13	1,744	1,789	1,834	1,879	1,924	1,969	2,014	2,059	2,104	2,149
14	2,566	2,633	2,699	2,765	2,831	2,898	2,964	3,030	3,096	3,163
15	3,380	3,468	3,555	3,642	3,729	3,817	3,904	3,991	4,078	4,166
16	2,374	2,436	2,497	2,558	2,619	2,681	2,742	2,803	2,865	2,926
17	1,781	1,827	1,873	1,919	1,965	2,011	2,057	2,103	2,149	2,195
18	1,629	1,671	1,713	1,755	1,797	1,839	1,881	1,923	1,965	2,008
19	4,414	4,528	4,642	4,756	4,870	4,984	5,098	5,212	5,326	5,440
20	3,285	3,370	3,454	3,539	3,624	3,709	3,794	3,878	3,963	4,048

values are listed in Table 7.18, and the time path of employment by occupation is graphed in Figures 7.15, 7.16, and 7.17. Note that the scales on the vertical axes are not the same on all figures.

The solution values were obtained using the Iowa State University computer (IBM 360) and a program with the code name "Zorilla" (88). This program is specifically designed to optimize a quadratic and linear form summed, subject to linear restraints, and is operational as long as the quadratic form is positive semi-definite for a minimization problem (88, p.2). The quadratic form in the problem at hand is positive definite, which not only guarantees a solution but insures that this solution will be unique (52, p. 213). It is easily seen that the quadratic form is positive definite. $\Sigma_j [r_j (x^*_{jT} - x_{jt})/x^*_{jT}]^2 = \Sigma_j [r_j^2 - 2 r_j^2 x_{jt}/x^*_{jT} + r_j^2 x_{jt}^2/x^{*2}_{jT}]$, so the matrix D of the generalized quadratic form X'Dx is a diagonal matrix with elements r_j^2/x^{*2}_{jT}. Since both r_j and x^*_{jT} are squared, all diagonal elements are positive. Then the determinant of D and all principal subdeterminants are positive, which is one means of defining a positive definite form (76, p.94).

The following objective function is written in the expanded form, ignoring the additive constants r_j^2. These constants are irrelevant in the optimization process. Since only the constraint matrix changes from year to year, the following function is applicable for all ten time periods. The following pages list the constraint matrices for each period.

$$
\begin{aligned}
\text{Min.}\quad & -\,[1039.70256\, x_1 + 634.28893\, x_2 + 1895.99775\, x_3 + 633.95347\, x_4 + \\
& + 895.34964\, x_5 + 470.38854\, x_6 + 1917.81134\, x_7 + 4464.63559\, x_8 + \\
& + 9001.99490\, x_9 + 5066.52006\, x_{10} + 3912.41470\, x_{11} + 1453.54779\, x_{12} + \\
& + 137.31111\, x_{13} + 2092.89068\, x_{14} + 1665.59123\, x_{15} + 38.36435\, x_{16} + \\
& + 48.91716\, x_{17} + 20.82600\, x_{18} + 6859.79824\, x_{19} + 4523.72505\, x_{20}] + \\
+\,1/2\quad & [3.62604\, x_1^2 + 5.31997\, x_2^2 + 76.34070\, x_3^2 + 20.80105\, x_4^2 + \\
& + 15.42111\, x_5^2 + 6.46502\, x_6^2 + 87.51934\, x_7^2 + 240.31842\, x_8^2 + \\
& + 997.67205\, x_9^2 + 696.33316\, x_{10}^2 + 398.45348\, x_{11}^2 + 11.42672\, x_{12}^2 + \\
& + 1.64681\, x_{13}^2 + 175.46032\, x_{14}^2 + 64.74350\, x_{15}^2 + .06905\, x_{16}^2 + \\
& + .20140\, x_{17}^2 + .04337\, x_{18}^2 + 640.74334\, x_{19}^2 + 501.52162\, x_{20}^2]
\end{aligned}
$$

Note that demand has been coded to three decimal places and the entire objective function was divided by the constant two. This was necessary to accommodate the data to the computer program. Multiplication of the objective function by any constant has no effect upon the results.

$$
\begin{aligned}
x_{1,51} &\leq .9830\, x_{1,50} + 6{,}329\\
x_{2,51} &\leq .9879\, x_{2,50} + 4{,}130\\
x_{3,51} &\leq .9865\, x_{3,50} + 1{,}005\\
x_{4,51} &\leq .9340\, x_{4,50} + 2{,}079\\
x_{5,51} &\leq .9893\, x_{5,50} + 2{,}249\\
x_{6,51} &\leq .9964\, x_{6,50} + 1{,}146\\
x_{7,51} &\leq 19{,}471\\
x_{8,51} &\leq .9878\, x_{8,50} + 495\\
x_{9,51} &\leq .9857\, x_{9,50} + 400\\
x_{10,51} &\leq .9942\, x_{10,50} + 424\\
x_{11,51} &\leq .9942\, x_{11,50} + 581\\
x_{12,51} &\leq .9859\, x_{12,50} + 2{,}830\\
x_{13,51} &\leq 58{,}018\\
x_{14,51} &\leq .9897\, x_{14,50} + 562\\
x_{15,51} &\leq .9946\, x_{15,50} + 1{,}120\\
x_{16,51} &\leq 381{,}619\\
x_{17,51} &\leq 147{,}588\\
x_{18,51} &\leq 300{,}000\\
x_{19,51} &\leq .9905\, x_{19,50} + 270\\
x_{20,51} &\leq .9904\, x_{20,50} + 107\\
x_{1,51} &\geq .9830\, x_{1,50}\\
x_{3,51} &\geq .9865\, x_{3,50}\\
x_{8,51} &\geq .9878\, x_{8,50}\\
x_{12,51} &\geq .9859\, x_{12,50}
\end{aligned}
$$

Fig. 7.5. 1951 constraint matrix.

$$x_{j,51} \quad (j \neq 1,\ 3,\ 8,\ 12) \qquad \geq 0$$

$$8{,}899\ x_{1,51} + 4{,}479\ x_{2,51} + 3{,}528\ x_{3,51} + 2{,}260\ x_{4,51} + 3{,}722\ x_{5,51} + 3{,}019\ x_{6,51}$$
$$+ 3{,}345\ x_{7,51} + 4{,}684\ x_{8,51} + 4{,}644\ x_{9,51} + 3{,}123\ x_{10,51} + 3{,}193\ x_{11,51} +$$
$$+ 7{,}001\ x_{12,51} + 1{,}744\ x_{13,51} + 2{,}566\ x_{14,51} + 3{,}380\ x_{15,51} + 2{,}374\ x_{16,51} +$$
$$+ 1{,}781\ x_{17,51} + 1{,}629\ x_{18,51} + 4{,}414\ x_{19,51} + 3{,}285\ x_{20,51} \qquad \leq 5{,}141{,}206{,}361$$

Fig. 5 (Continued).

$$
\begin{aligned}
x_{1,52} &\le .9832\ x_{1,51} + 6{,}508 \\
x_{2,52} &\le .9879\ x_{2,51} + 2{,}893 \\
x_{3,52} &\le .9865\ x_{3,51} + 955 \\
x_{4,52} &\le .9340\ x_{4,51} + 2{,}079 \\
x_{5,52} &\le .9843\ x_{5,51} + 2{,}525 \\
x_{6,52} &\le .9964\ x_{6,51} + 1{,}398 \\
x_{7,52} &\le 19{,}743 \\
x_{8,52} &\le .9878\ x_{8,51} + 509 \\
x_{9,52} &\le .9857\ x_{9,51} + 450 \\
x_{10,52} &\le .9942\ x_{10,51} + 457 \\
x_{11,52} &\le .9942\ x_{11,51} + 620 \\
x_{12,52} &\le .9859\ x_{12,51} + 2{,}927 \\
x_{13,52} &\le 60{,}836 \\
x_{14,52} &\le .9897\ x_{14,51} + 594 \\
x_{15,52} &\le .9946\ x_{15,51} + 1{,}120 \\
x_{16,52} &\le 396{,}355 \\
x_{17,52} &\le 158{,}176 \\
x_{18,52} &\le 350{,}000 \\
x_{19,52} &\le .9905\ x_{19,51} + 171 \\
x_{20,52} &\le .9904\ x_{20,51} + 113 \\
x_{1,52} &\ge .9832\ x_{1,51} \\
x_{3,52} &\ge .9865\ x_{3,51} \\
x_{8,52} &\ge .9878\ x_{8,51} \\
x_{12,52} &\ge .9859\ x_{12,51}
\end{aligned}
$$

Fig. 7.6. 1952 constraint matrix.

$$x_{j,52} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$9{,}128\ x_{1,52} + 4{,}594\ x_{2,52} + 3{,}619\ x_{3,52} + 2{,}319\ x_{4,52} + 3{,}818\ x_{5,52} + 3{,}097\ x_{6,52}$$
$$+ 3{,}432\ x_{7,52} + 4{,}805\ x_{8,52} + 4{,}764\ x_{9,52} + 3{,}203\ x_{10,52} + 3{,}276\ x_{11,52}$$
$$+ 7{,}181\ x_{12,52} + 1{,}789\ x_{13,52} + 2{,}633\ x_{14,52} + 3{,}468\ x_{15,52} + 2{,}436\ x_{16,52} +$$
$$+ 1{,}827\ x_{17,52} + 1{,}671\ x_{18,52} + 4{,}528\ x_{19,52} + 3{,}370\ x_{20,52} \qquad \leq 5{,}432{,}791{,}166$$

Fig. 6 (Continued).

$$
\begin{aligned}
x_{1,53} &\leq .9835\ x_{1,52} + 6{,}779 \\
x_{2,53} &\leq .9879\ x_{2,52} + 2{,}282 \\
x_{3,53} &\leq .9865\ x_{3,52} + 838 \\
x_{4,53} &\leq .9340\ x_{4,52} + 2{,}079 \\
x_{5,53} &\leq .9893\ x_{5,52} + 2{,}816 \\
x_{6,53} &\leq .9964\ x_{6,52} + 1{,}706 \\
x_{7,53} &\leq 20{,}014 \\
x_{8,53} &\leq .9878\ x_{8,52} + 522 \\
x_{9,53} &\leq .9857\ x_{9,52} + 500 \\
x_{10,53} &\leq .9942\ x_{10,52} + 490 \\
x_{11,53} &\leq .9942\ x_{11,52} + 672 \\
x_{12,53} &\leq .9859\ x_{12,52} + 2{,}922 \\
x_{13,53} &\leq 63{,}654 \\
x_{14,53} &\leq .9897\ x_{14,52} + 625 \\
x_{15,53} &\leq .9946\ x_{15,52} + 1{,}120 \\
x_{16,53} &\leq 410{,}241 \\
x_{17,53} &\leq 168{,}764 \\
x_{18,53} &\leq 350{,}000 \\
x_{19,53} &\leq .9905\ x_{19,52} + 176 \\
x_{20,53} &\leq .9904\ x_{20,52} + 174 \\
x_{1,53} &\geq .9835\ x_{1,52} \\
x_{3,53} &\geq .9865\ x_{3,52} \\
x_{8,53} &\geq .9878\ x_{8,52} \\
x_{12,53} &\geq .9859\ x_{12,52}
\end{aligned}
$$

Fig. 7.7. 1953 constraint matrix.

$$x_{j,53} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$9{,}358\ x_{1,53} + 4{,}710\ x_{2,53} + 3{,}710\ x_{3,53} + 2{,}377\ x_{4,53} + 3{,}914\ x_{5,53} + 3{,}175\ x_{6,53}$$
$$+ 3{,}518\ x_{7,53} + 4{,}926\ x_{8,53} + 4{,}884\ x_{9,53} + 3{,}284\ x_{10,53} + 3{,}358\ x_{11,53} +$$
$$+ 7{,}362\ x_{12,53} + 1{,}834\ x_{13,53} + 2{,}699\ x_{14,53} + 3{,}555\ x_{15,53} + 2{,}497\ x_{16,53} +$$
$$1{,}873\ x_{17,53} + 1{,}713\ x_{18,53} + 4{,}642\ x_{19,53} + 3{,}454\ x_{20,53} \qquad \leq 5{,}732{,}075{,}778$$

Fig. 7 (Continued).

$$
\begin{array}{ll}
x_{1,54} & \leq .9837\ x_{1,53} + 6{,}967 \\
x_{2,54} & \leq .9879\ x_{2,53} + 2{,}326 \\
x_{3,54} & \leq .9865\ x_{3,53} + 853 \\
x_{4,54} & \leq .9340\ x_{4,53} + 2{,}079 \\
x_{5,54} & \leq .9893\ x_{5,53} + 3{,}121 \\
x_{6,54} & \leq .9964\ x_{6,53} + 2{,}081 \\
x_{7,54} & \leq 20{,}285 \\
x_{8,54} & \leq .9878\ x_{8,53} + 536 \\
x_{9,54} & \leq .9857\ x_{9,53} + 550 \\
x_{10,54} & \leq .9942\ x_{10,53} + 523 \\
x_{11,54} & \leq .9942\ x_{11,53} + 724 \\
x_{12,54} & \leq .9859\ x_{12,53} + 3{,}000 \\
x_{13,54} & \leq 66{,}472 \\
x_{14,54} & \leq .9897\ x_{14,53} + 657 \\
x_{15,54} & \leq .9946\ x_{15,53} + 1{,}120 \\
x_{16,54} & \leq 423{,}658 \\
x_{17,54} & \leq 179{,}352 \\
x_{18,54} & \leq 350{,}000 \\
x_{19,54} & \leq .9905\ x_{19,53} + 181 \\
x_{20,54} & \leq .9904\ x_{20,53} + 237 \\
x_{1,54} & \geq .9837\ x_{1,53} \\
x_{3,54} & \geq .9865\ x_{3,53} \\
x_{8,54} & \geq .9878\ x_{8,53} \\
x_{12,54} & \geq .9859\ x_{12,53}
\end{array}
$$

Fig. 7.8. 1954 constraint matrix.

$$x_{j,54} \quad (j \neq 1,\ 3,\ 8,\ 12) \qquad \geq 0$$

$$9{,}588\ x_{1,54} + 4{,}825\ x_{2,54} + 3{,}801\ x_{3,54} + 2{,}435\ x_{4,54} + 4{,}010\ x_{5,54} + 3{,}253\ x_{6,54}$$

$$+ 3{,}604\ x_{7,54} + 5{,}047\ x_{8,54} + 5{,}004\ x_{9,54} + 3{,}364\ x_{10,54} + 3{,}441\ x_{11,54} +$$

$$+ 7{,}543\ x_{12,54} + 1{,}879\ x_{13,54} + 2{,}765\ x_{14,54} + 3{,}642\ x_{15,54} + 2{,}558\ x_{16,54} +$$

$$+ 1{,}919\ x_{17,54} + 1{,}755\ x_{18,54} + 4{,}756\ x_{19,54} + 3{,}539\ x_{20,54} \qquad \leq 6{,}039{,}060{,}196$$

Fig. 8 (Continued).

$$
\begin{array}{lll}
x_{1,55} & \leq & .9840\ x_{1,54} + 7{,}242 \\
x_{2,55} & \leq & .9879\ x_{2,54} + 2{,}370 \\
x_{3,55} & \leq & .9865\ x_{3,54} + 868 \\
x_{4,55} & \leq & .9340\ x_{4,54} + 2{,}079 \\
x_{5,55} & \leq & .9893\ x_{5,54} + 3{,}442 \\
x_{6,55} & \leq & .9964\ x_{6,54} + 2{,}538 \\
x_{7,55} & \leq & 20{,}557 \\
x_{8,55} & \leq & .9878\ x_{8,54} + 550 \\
x_{9,55} & \leq & .9857\ x_{9,54} + 600 \\
x_{10,55} & \leq & .9942\ x_{10,54} + 556 \\
x_{11,55} & \leq & .9942\ x_{11,54} + 776 \\
x_{12,55} & \leq & .9859\ x_{12,54} + 3{,}000 \\
x_{13,55} & \leq & 69{,}290 \\
x_{14,55} & \leq & .9897\ x_{14,54} + 689 \\
x_{15,55} & \leq & .9946\ x_{15,54} + 1{,}120 \\
x_{16,55} & \leq & 436{,}893 \\
x_{17,55} & \leq & 189{,}940 \\
x_{18,55} & \leq & 350{,}585 \\
x_{19,55} & \leq & .9905\ x_{19,54} + 186 \\
x_{20,55} & \leq & .9904\ x_{20,54} + 317 \\
x_{1,55} & \geq & .9840\ x_{1,54} \\
x_{3,55} & \geq & .9865\ x_{3,54} \\
x_{8,55} & \geq & .9878\ x_{8,54} \\
x_{12,55} & \geq & .9859\ x_{12,54}
\end{array}
$$

Fig. 7.9. 1955 constraint matrix.

$$x_{j,55} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$9{,}818\ x_{1,55} + 4{,}941\ x_{2,55} + 3{,}892\ x_{3,55} + 2{,}494\ x_{4,55} + 4{,}106\ x_{5,55} + 3{,}331\ x_{6,55}$$

$$+ 3{,}691\ x_{7,55} + 5{,}168\ x_{8,55} + 5{,}123\ x_{9,55} + 3{,}445\ x_{10,55} + 3{,}523\ x_{11,55} +$$

$$7{,}724\ x_{12,55} + 1{,}924\ x_{13,55} + 2{,}831\ x_{14,55} + 3{,}729\ x_{15,55} + 2{,}619\ x_{16,55} +$$

$$+ 1{,}965\ x_{17,55} + 1{,}797\ x_{18,55} + 4{,}870\ x_{19,55} + 3{,}624\ x_{20,55} \qquad \leq 6{,}353{,}744{,}420$$

Fig. 9 (Continued).

$$
\begin{aligned}
x_{1,56} &\le .9843\, x_{1,55} + 7{,}478 \\
x_{2,56} &\le .9888\, x_{2,55} + 2{,}413 \\
x_{3,56} &\le .9870\, x_{3,55} + 883 \\
x_{4,56} &\le .9340\, x_{4,55} + 2{,}406 \\
x_{5,56} &\le .9896\, x_{5,55} + 3{,}778 \\
x_{6,56} &\le .9969\, x_{6,55} + 3{,}096 \\
x_{7,56} &\le 20{,}828 \\
x_{8,56} &\le .9887\, x_{8,55} + 563 \\
x_{9,56} &\le .9854\, x_{9,55} + 650 \\
x_{10,56} &\le .9950\, x_{10,55} + 589 \\
x_{11,56} &\le .9950\, x_{11,55} + 829 \\
x_{12,56} &\le .9868\, x_{12,55} + 3{,}000 \\
x_{13,56} &\le 72{,}108 \\
x_{14,56} &\le .9901\, x_{14,55} + 720 \\
x_{15,56} &\le .9951\, x_{15,55} + 1{,}120 \\
x_{16,56} &\le 450{,}075 \\
x_{17,56} &\le 200{,}528 \\
x_{18,56} &\le 376{,}501 \\
x_{19,56} &\le .9912\, x_{19,55} + 192 \\
x_{20,56} &\le .9911\, x_{20,55} + 415 \\
x_{1,56} &\ge .9843\, x_{1,55} \\
x_{3,56} &\ge .9870\, x_{3,55} \\
x_{8,56} &\ge .9887\, x_{8,55} \\
x_{12,56} &\ge .9868\, x_{12,55}
\end{aligned}
$$

Fig. 7.10. 1956 constraint matrix.

$$x_{j,56} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$10{,}047\ x_{1,56} + 5{,}057\ x_{2,56} + 3{,}983\ x_{3,56} + 2{,}552\ x_{4,56} + 4{,}203\ x_{5,56} + 3{,}409\ x_{6,56}$$

$$+ 3{,}777\ x_{7,56} + 5{,}289\ x_{8,56} + 5{,}243\ x_{9,56} + 3{,}526\ x_{10,56} + 3{,}606\ x_{11,56} +$$

$$+ 7{,}904\ x_{12,56} + 1{,}969\ x_{13,56} + 2{,}898\ x_{14,56} + 3{,}817\ x_{15,56} + 2{,}681\ x_{16,56} +$$

$$+ 2{,}011\ x_{17,56} + 1{,}839\ x_{18,56} + 4{,}984\ x_{19,56} + 3{,}709\ x_{20,56} \qquad \leq 6{,}676{,}128{,}451$$

Fig. 10 (Continued).

$$
\begin{aligned}
x_{1,57} &\le .9845\ x_{1,56} + 7{,}714 \\
x_{2,57} &\le .9888\ x_{2,56} + 2{,}458 \\
x_{3,57} &\le .9870\ x_{3,56} + 898 \\
x_{4,57} &\le .9340\ x_{4,56} + 2{,}406 \\
x_{5,57} &\le .9896\ x_{5,56} + 4{,}128 \\
x_{6,57} &\le .9969\ x_{6,56} + 3{,}777 \\
x_{7,57} &\le 21{,}099 \\
x_{8,57} &\le .9887\ x_{8,56} + 577 \\
x_{9,57} &\le .9854\ x_{9,56} + 700 \\
x_{10,57} &\le .9950\ x_{10,56} + 622 \\
x_{11,57} &\le .9950\ x_{11,56} + 881 \\
x_{12,57} &\le .9868\ x_{12,56} + 3{,}000 \\
x_{13,57} &\le 74{,}926 \\
x_{14,57} &\le .9901\ x_{14,56} + 752 \\
x_{15,57} &\le .9951\ x_{15,56} + 1{,}120 \\
x_{16,57} &\le 463{,}324 \\
x_{17,57} &\le 211{,}116 \\
x_{18,57} &\le 402{,}418 \\
x_{19,57} &\le .9912\ x_{19,56} + 197 \\
x_{20,57} &\le .9911\ x_{20,56} + 538 \\
x_{1,57} &\ge .9845\ x_{1,56} \\
x_{3,57} &\ge .9870\ x_{3,56} \\
x_{8,57} &\ge .9887\ x_{8,56} \\
x_{12,57} &\ge .9868\ x_{12,56}
\end{aligned}
$$

Fig. 7.11. 1957 constraint matrix.

$$x_{j,57} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$10{,}277\, x_{1,57} + 5{,}172\, x_{2,57} + 4{,}075\, x_{3,57} + 2{,}610\, x_{4,57} + 4{,}299\, x_{5,57} + 3{,}487\, x_{6,57}$$

$$+\, 3{,}864\, x_{7,57} + 5{,}409\, x_{8,57} + 5{,}363\, x_{9,57} + 3{,}606\, x_{10,57} + 3{,}688\, x_{11,57} +$$

$$+\, 8{,}085\, x_{12,57} + 2{,}014\, x_{13,57} + 2{,}964\, x_{14,57} + 3{,}904\, x_{15,57} + 2{,}742\, x_{16,57} +$$

$$+\, 2{,}057\, x_{17,57} + 1{,}881\, x_{18,57} + 5{,}098\, x_{19,57} + 3{,}794\, x_{20,57} \qquad \leq 7{,}006{,}212{,}288$$

Fig. 11 (Continued).

$$
\begin{aligned}
x_{1,58} &\le .9849\, x_{1,57} + 7{,}951 \\
x_{2,58} &\le .9888\, x_{2,57} + 2{,}502 \\
x_{3,58} &\le .9870\, x_{3,57} + 913 \\
x_{4,58} &\le .9340\, x_{4,57} + 2{,}406 \\
x_{5,58} &\le .9896\, x_{5,57} + 4{,}493 \\
x_{6,58} &\le .9969\, x_{6,57} + 4{,}607 \\
x_{7,58} &\le 21{,}370 \\
x_{8,58} &\le .9887\, x_{8,57} + 591 \\
x_{9,58} &\le .9854\, x_{9,57} + 750 \\
x_{10,58} &\le .9950\, x_{10,57} + 655 \\
x_{11,58} &\le .9950\, x_{11,57} + 932 \\
x_{12,58} &\le .9868\, x_{12,57} + 3{,}000 \\
x_{13,58} &\le 77.744 \\
x_{14,58} &\le .9901\, x_{14,57} + 784 \\
x_{15,58} &\le .9951\, x_{15,57} + 1{,}120 \\
x_{16,58} &\le 476{,}642 \\
x_{17,58} &\le 221{,}704 \\
x_{18,58} &\le 428{,}335 \\
x_{19,58} &\le .9912\, x_{19,57} + 202 \\
x_{20,58} &\le .9911\, x_{20,57} + 687 \\
x_{1,58} &\ge .9848\, x_{1,57} \\
x_{3,58} &\ge .9870\, x_{3,57} \\
x_{8,58} &\ge .9887\, x_{8,57} \\
x_{12,58} &\ge .9868\, x_{12,57}
\end{aligned}
$$

Fig. 7.12. 1958 constraint matrix.

$$x_{j,58} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$10{,}507\, x_{1,58} + 5{,}288\, x_{2,58} + 4{,}166\, x_{3,58} + 2{,}669\, x_{4,58} + 4{,}395\, x_{5,58} + 3{,}564\, x_{6,58}$$

$$+ 3{,}950\, x_{7,58} + 5{,}530\, x_{8,58} + 5{,}483\, x_{9,58} + 3{,}687\, x_{10,58} + 3{,}771\, x_{11,58} +$$

$$+ 8{,}266\, x_{12,58} + 2{,}059\, x_{13,58} + 3{,}030\, x_{14,58} + 3{,}991\, x_{15,58} + 2{,}803\, x_{16,58} +$$

$$+ 2{,}103\, x_{17,58} + 1{,}923\, x_{18,58} + 5{,}212\, x_{19,58} + 3{,}878\, x_{20,58} \qquad \leq 7{,}343{,}995{,}932$$

Fig. 12 (Continued).

$$x_{1,59} \leq .9850\, x_{1,58} + 8{,}187$$
$$x_{2,59} \leq .9888\, x_{2,58} + 2{,}545$$
$$x_{3,59} \leq .9870\, x_{3,58} + 928$$
$$x_{4,59} \leq .9340\, x_{4,58} + 2{,}406$$
$$x_{5,59} \leq .9876\, x_{5,58} + 4{,}873$$
$$x_{6,59} \leq .9969\, x_{6,58} + 5{,}620$$
$$x_{7,59} \leq 21{,}642$$
$$x_{8,59} \leq .9887\, x_{8,58} + 605$$
$$x_{9,59} \leq .9854\, x_{9,58} + 800$$
$$x_{10,59} \leq .9950\, x_{10,58} + 688$$
$$x_{11,59} \leq .9950\, x_{11,58} + 985$$
$$x_{12,59} \leq .9868\, x_{12,58} + 3{,}000$$
$$x_{13,59} \leq 80{,}562$$
$$x_{14,59} \leq .9901\, x_{14,58} + 816$$
$$x_{15,59} \leq .9951\, x_{15,58} + 1{,}120$$
$$x_{16,59} \leq 490{,}062$$
$$x_{17,59} \leq 232{,}292$$
$$x_{18,59} \leq 454{,}252$$
$$x_{19,59} \leq .9912\, x_{19,58} + 207$$
$$x_{20,59} \leq .9911\, x_{20,58} + 867$$
$$x_{1,59} \geq .9850\, x_{1,58}$$
$$x_{3,59} \geq .9870\, x_{3,58}$$
$$x_{8,59} \geq .9887\, x_{8,58}$$
$$x_{12,59} \geq .9868\, x_{12,58}$$

Fig. 7.13. 1959 constraint matrix.

$$x_{j,59} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$$

$$10{,}737\ x_{1,59} + 5{,}404\ x_{2,59} + 4{,}257\ x_{3,59} + 2{,}727\ x_{4,59} + 4{,}491\ x_{5,59} + 3{,}642\ x_{6,59}$$
$$+ 4{,}036\ x_{7,59} + 5{,}651\ x_{8,59} + 5{,}603\ x_{9,59} + 3{,}768\ x_{10,59} + 3{,}853\ x_{11,59} +$$
$$+ 8{,}447\ x_{12,59} + 2{,}104\ x_{13,59} + 3{,}096\ x_{14,59} + 4{,}078\ x_{15,59} + 2{,}865\ x_{16,59} +$$
$$+ 2{,}149\ x_{17,59} + 1{,}965\ x_{18,59} + 5{,}326\ x_{19,59} + 3{,}963\ x_{20,59} \qquad \leq 7{,}689{,}479{,}382$$

Fig. 13 (Continued).

$$
\begin{array}{lll}
x_{1,60} & \leq & .9853\ x_{1,59} + 8,423 \\
x_{2,60} & \leq & .9888\ x_{2,59} + 2,589 \\
x_{3,60} & \leq & .9870\ x_{3,59} + 943 \\
x_{4,60} & \leq & .9340\ x_{4,59} + 2,406 \\
x_{5,60} & \leq & .9896\ x_{5,59} + 5,268 \\
x_{6,60} & \leq & .9969\ x_{6,59} + 6,855 \\
x_{7,60} & \leq & 21,913 \\
x_{8,60} & \leq & .9887\ x_{8,59} + 618 \\
x_{9,60} & \leq & .9854\ x_{9,59} + 850 \\
x_{10,60} & \leq & .9950\ x_{10,59} + 721 \\
x_{11,60} & \leq & .9950\ x_{11,59} + 1,037 \\
x_{12,60} & \leq & .9868\ x_{12,59} + 3,000 \\
x_{13,60} & \leq & 83,380 \\
x_{14,60} & \leq & .9901\ x_{14,59} + 847 \\
x_{15,60} & \leq & .9951\ x_{15,59} + 1,120 \\
x_{16,60} & \leq & 503,607 \\
x_{17,60} & \leq & 242,880 \\
x_{18,60} & \leq & 480,169 \\
x_{19,60} & \leq & .9912\ x_{19,59} + 212 \\
x_{20,60} & \leq & .9911\ x_{20,59} + 1,083 \\
x_{1,60} & \geq & .9853\ x_{1,59} \\
x_{3,60} & \geq & .9870\ x_{3,59} \\
x_{8,60} & \geq & .9887\ x_{8,59} \\
x_{12,60} & \geq & .9868\ x_{12,59}
\end{array}
$$

Fig. 7.14. 1960 constraint matrix.

$x_{j,60} \quad (j \neq 1, 3, 8, 12) \qquad \geq 0$

$$\begin{aligned}
&10{,}966\ x_{1,60} + 5{,}519\ x_{2,60} + 4{,}348\ x_{3,60} + 2{,}786\ x_{4,60} + 4{,}587\ x_{5,60} + 3{,}720\ x_{6,60} \\
&+ 4{,}123\ x_{7,60} + 5{,}772\ x_{8,60} + 5{,}723\ x_{9,60} + 3{,}848\ x_{10,60} + 3{,}935\ x_{11,60} + \\
&+ 8{,}627\ x_{12,60} + 2{,}149\ x_{13,60} + 3{,}163\ x_{14,60} + 4{,}166\ x_{15,60} + 2{,}926\ x_{16,60} + \\
&+ 2{,}195\ x_{17,60} + 2{,}008\ x_{18,60} + 5{,}440\ x_{19,60} + 4{,}048\ x_{20,60} \qquad \leq 8{,}042{,}662{,}638
\end{aligned}$$

Fig. 14 (Continued).

Table 7.18. Employment by Occupation, 1951 - 1960, as Forecast by Recursive Program

Occupation Code	Year									
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
1	189,953	193,270	196,860	200,618	204,650	208,915	213,391	218,078	223,811	228,944
2	104,007	105,642	106,646	107,682	108,749	109,944	111,171	112,428	113,714	115,029
3	20,735	21,410	21,959	22,516	23,080	23,663	24,253	24,707	24,717	24,730
4	22,647	23,213	23,760	24,271	24,748	25,521	26,243	26,917	27,546	28,134
5	31,928	34,111	36,562	39,292	42,314	45,652	47,426	49,201	53,562	57,506
6	31,835	33,118	34,705	36,661	39,067	42,042	45,689	50,154	55,619	62,302
7	19,471	19,743	20,014	20,285	20,557	20,828	21,099	21,370	21,642	21,825
8	18,078	18,366	18,496	18,502	18,507	18,512	18,519	18,524	18,528	18,533
9	3,357	3,759	4,205	4,695	5,228	5,802	6,417	7,073	7,770	8,507
10	2,711	3,152	3,624	4,126	4,658	5,224	5,820	6,446	7,102	7,266
11	5,154	5,744	6,383	7,070	7,805	8,595	9,433	9,797	9,798	9,801
12	80,634	82,424	84,184	85,997	87,784	89,625	91,442	93,235	95,004	96,750
13	58,018	60,836	63,564	66,472	69,290	72,108	74,926	77,744	80,652	80,948
14	7,490	8,007	8,550	9,119	9,714	10,338	10,988	11,663	11,890	11,894
15	22,007	23,008	24,004	24,994	25,538	25,521	25,568	25,583	25,591	25,606
16	381,619	396,355	409,535	421,049	431,493	440,433	451,688	459,735	467,101	476,618
17	147,588	158,176	168,764	179,352	189,940	200,528	211,116	218,225	220,126	222,571
18	296,648	322,565	-20,654	333,217	344,614	354,417	366,699	375,480	383,551	393,893
19	6,213	6,325	6,441	6,561	6,685	6,818	6,955	7,096	7,241	7,389
20	5,059	5,123	5,248	5,435	5,700	6,064	6,548	7,177	7,980	8,992

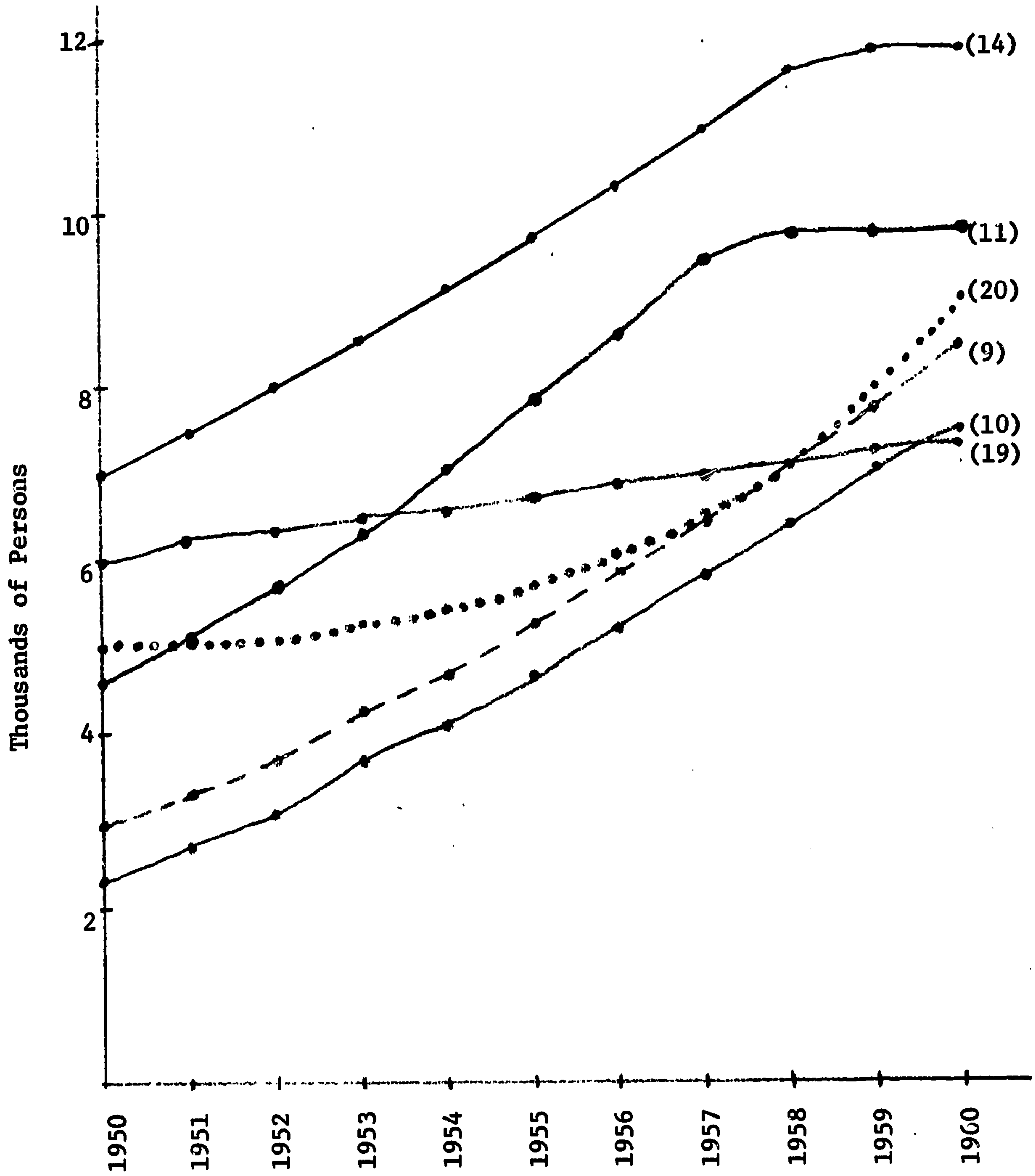

Fig. 7.15. Time path of employment.

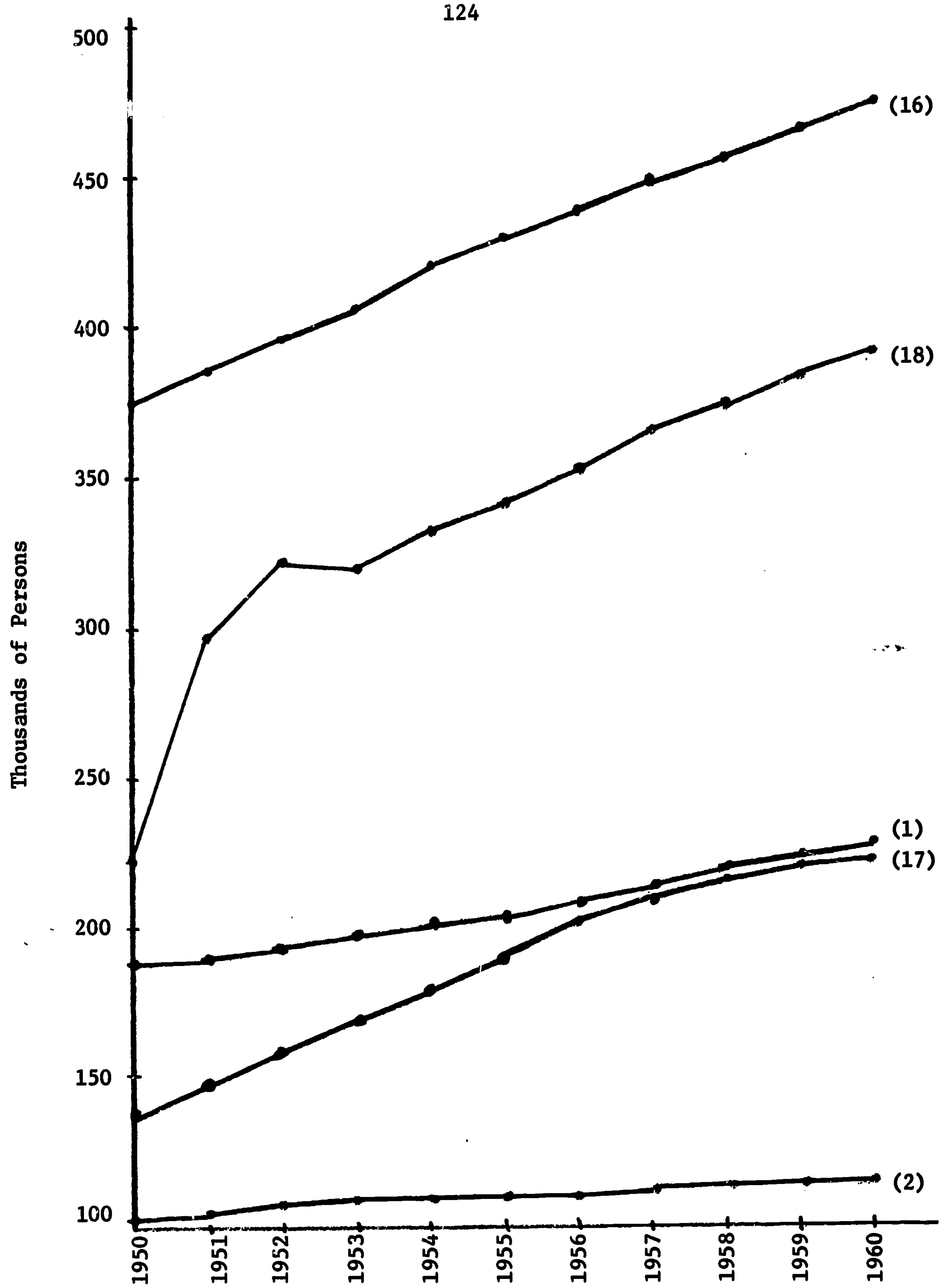

Fig. 7.16. Time path of employment.

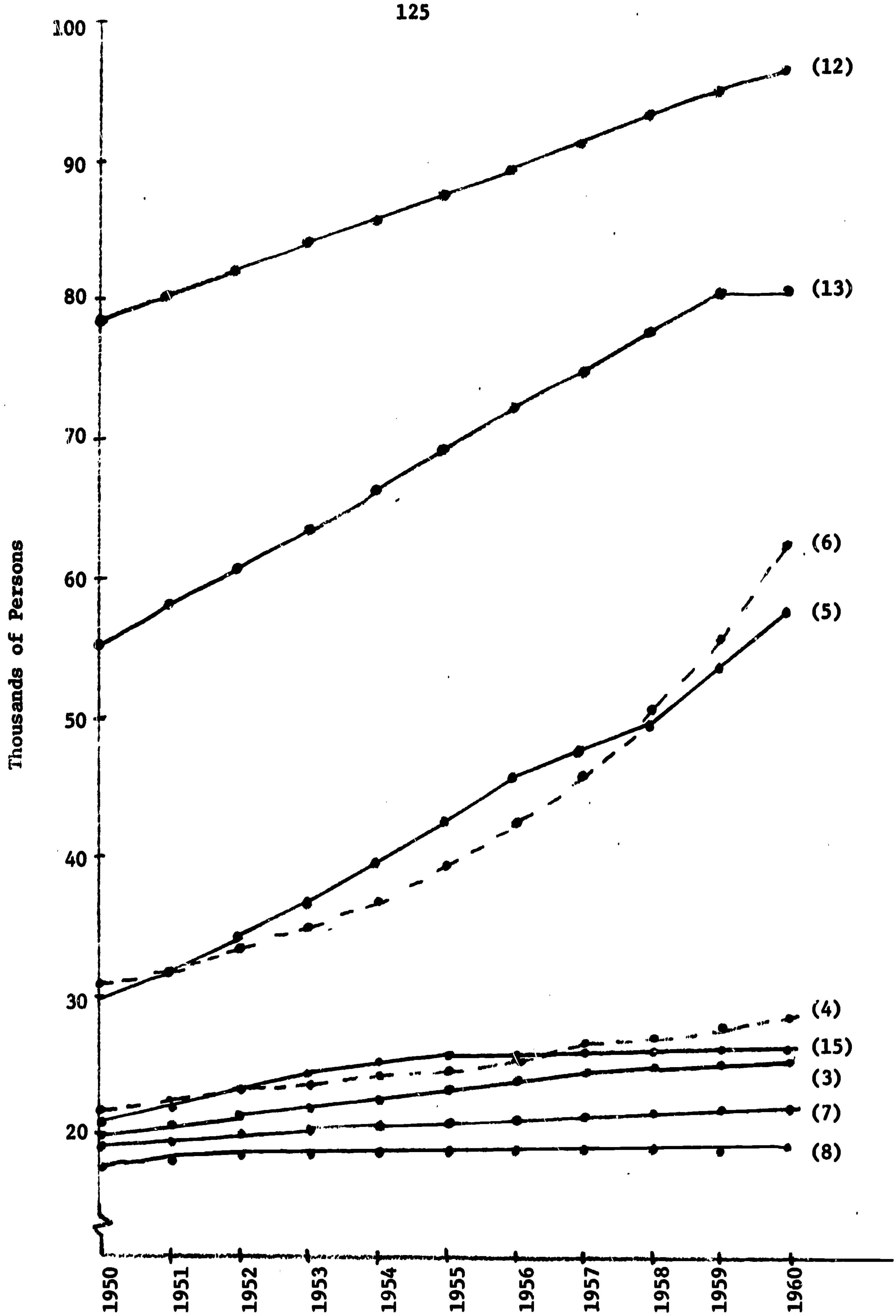

Fig. 7.17. Time path of employment.

CHAPTER VIII: EVALUATION AND COMPARISON OF ESTIMATES

Tables 8.1 and 8.2 detail the differences between actual employment in 1960 and the forecasts generated using the naive model and the recursive programming model respectively.

Table 8.1. Employment by Occupation, 1960, Actual and as Forecast by Naive Model, Absolute and Percentage Differences as Deviations From Actual

Occupation Code	Actual Employment	Forecast Employment	Difference	Percentage Difference
1	219,200[a]	213,408	- 5,792	- 2.6
2	117,000	118,560	1,560	1.3
3	25,000	24,836	- 164	- 0.7
4	26,000	25,811	- 189	- 0.7
5	68,000	57,493	- 10,507	- 15.5
6	70,000	72,193	2,193	3.1
7	20,300	21,913	1,613	7.9
8	17,300	18,578	1,278	7.4
9	8,000	6,046	- 1,954	- 24.4
10	8,000	5,307	- 2,693	- 33.7
11	9,000	9,333	333	3.7
12	92,220[a]	83,925	- 8,295	- 9.0
13	82,500	83,380	880	1.1
14	12,500	11,928	- 572	- 4.6
15	25,000	25,725	725	2.9
16	504,000	530,518	26,518	5.3
17	206,000	184,630	- 21,370	- 10.4
18	375,000	434,356	59,356	15.8
19	8,000	10,706	2,706	33.8
20	11,000	9,020	- 1,980	- 18.0

Source: Column 1 (107, p.14), Column 2 (Table 7.11).

[a]Adjusted for inactives. All other data for actives only in original source.

The naive model forecast total employment for the twenty occupations considered with an error of 2.3%, while the recursive program forecast the same magnitude with an error of only .02%. These figures are not meaningful, however, in comparing the two forecasts. For the naive model, the average

Table 8.2. Employment by Occupation, 1960, Actual and as Forecast by Recursive Program, Absolute and Percentage Difference as Deviation From Actual

Occupation Code	Actual Employment	Forecast Employment	Difference	Percentage Difference
1	219,200[a]	228,944	9,744	4.4
2	117,000	115,029	- 1,971	- 1.7
3	25,000	24,730	- 270	- 1.1
4	26,000	28,134	2,134	8.2
5	68,000	57,506	- 10,494	- 15.4
6	70,000	62,302	- 7,698	- 11.0
7	20,300	21,825	1,525	7.5
8	17,300	18,533	1,233	7.1
9	8,000	8,507	507	6.3
10	8,000	7,266	- 734	- 9.2
11	9,000	9,801	801	8.9
12	92,220[a]	96,750	4,530	4.9
13	82,500	80,948	- 1,552	- 1.9
14	12,500	11,894	- 606	- 4.8
15	25,000	25,606	606	2.4
16	504,000	476,618	- 27,382	- 5.4
17	206,000	222,571	16,571	[illegible]
18	375,000	393,893	18,893	5.0
19	8,000	7,389	- 611	- 7.6
20	11,000	8,992	- 2,008	- 18.3

Source: Column 1 (107, p.14), Column 2 (Table 7.18).

[a]Adjusted for inactives. All other data for actives only in original source.

absolute percentage difference was 10.10%, while for the recursive program this was 6.96%. The average negative percentage difference for the naive model is 11.96%, while the average positive difference is 8.23%. The comparable figures for the recursive program are 7.64% average negative difference and 6.27% average positive difference. Because differences are defined as forecast minus actual, both models exhibit a conservative bias. Percentage deviations are larger for those occupations where the forecast underestimates employment than for those where the forecast is an overestimate, on the average.

Both models overestimated employment in ten occupations and underestimated

in the other ten. They did not both underestimate on the same occupations, however. There are ten occupations for which one model overestimated employment while the other underestimated. The fact that both forecasts contain as many positive deviations as negative deviations is simply a random occurrence. Many of the percentage deviations are so small that the sign is not really meaningful.

The recursive program appears to be the more consistent of the two models in forecasting. The naive model had percentage errors in excess of 10% for seven occupations and the recursive program for only three occupations. The naive model had percentage errors in excess of 20% for three occupations, while the largest deviation for the recursive program was 18.3%. The standard error of the absolute percentage deviations was 10.4 for the naive model and 4.3 for the recursive program. The mean of the algebraic deviations was -1.88% for the naive model and -.69% for the recursive programming model. The standard error of the algebraic percentage deviations was 14.5 for the naive model and 8.3 for the recursive program.

Given the nature and quality of the input data, I would establish the arbitrary figure of 5% error as a standard of accuracy. That is, any occupation for which the forecast was within 5% of actual employment in 1960 will be considered to have been forecast "accurately." Many of the errors of 5% and less are probably due to "accident" or compensating errors in estimating several parameters, but little knowledge can be gained regarding the workings of the model or possible flaws in its specification by analyzing these occupations. If the percentage error is less than 5, the difference could easily be due to poor data rather than an incorrect forecasting procedure.

A detailed analysis of probable reasons for large forecasting errors in both models is contained in the author's doctoral dissertation, previously

cited. This analysis is not reproduced herein because most of the conclusions rest on observations regarding specific procedures or assumptions which were not included in this abridged report. Some generalizations can be made, however. In most cases, those occupations for which the forecasting error was large were the same occupations for which data were of poor quality or of a fragmentary nature. However, the ability to forecast "reasonably well" using incomplete data is an essential quality for a useful model. Despite several statements to the effect that much more information regarding magnitudes of interest in implementing the model developed herein is available today than in 1950, the state of current information availabilities still leaves much to be desired.

The only possible error in the formulation of the model uncovered in the testing process relates to the determination of the r_j. These were previously defined as measuring the "relative urgency" of reducing excess demand as a percentage of total demand for a given occupation. However, even assuming that relative average annual earnings are a good estimate of relative marginal revenue products, the former are only proxies for the true r_j. This is because the procedure of using percentage deviations already accounts in some measure for "relative urgency." I am not certain what the best empirical estimate of r_j would be.

CHAPTER IX: CONCLUSION

The previous chapter illustrated some of the types of information available from an analysis of the forecast generated by the recursive programming model. This chapter is applied more directly to this aspect of the model as well as to a discussion of the usefulness of this information in policy making.

Usefulness of the Model as a Policy Tool

The recursive programming model, hereafter referred to simply as "the model," obviously yields information regarding supply of and demand for personnel in the target year. Note that information is available on both "ceteris paribus" demand and what I shall term "effective" demand. One may assume that the goal of the policy maker would be to equate supply to demand by offering various incentives to increase numbers of persons trained in occupations for which substantial excess demand is forecast, and to remove existing incentives, if any, for providing training in occupations expected to have a surplus of labor. Information useful in acting to achieve these goals is most conveniently obtained by analyzing the Lagrange multipliers, which are generated by the recursive program. These are listed in Table 9.1. These multipliers state the change in the objective function caused by increasing the constant in a supply constraint by one unit.

Referring to Table 9.1, we note that one additional physician trained would reduce the value of $\Sigma_j [r_j \, (x^*_{j,60} - x_{j,60}) \, / \, x^*_{j,60}]^2$ by 189.1 units in 1960. The values of the multipliers are expressed in the units of the objective function and are hence pure numbers expressing abstract values. For this reason, the multipliers are often referred to as "shadow prices." Because of the abstract nature of these multipliers, the absolute units

Table 9.1. Lagrance Multipliers

Occupation Code	Year									
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
1	308.4	298.1	288.1	277.4	265.5	252.4	239.0	224.1	205.3	189.1
2	55.6	51.7	47.9	43.9	39.6	34.4	29.3	23.7	17.8	12.1
3	286.4	245.4	204.6	163.3	121.3	77.7	33.9	-	-	-
4	151.6	140.7	130.1	120.2	111.0	95.5	81.2	67.7	55.2	43.5
5	388.8	352.2	315.7	274.9	229.4	178.9	187.4	126.2	59.8	-
6	251.6	242.4	233.2	221.6	206.9	188.5	165.9	137.7	103.0	60.7
7	197.2	174.6	152.0	129.4	106.6	83.8	61.1	38.2	15.1	-
8	37.2	29.4	-	-	-	-	-	-	-	-
9	5674.7	5230.4	4787.1	4299.7	3769.4	3197.9	2585.9	1932.5	1238.1	504.1
10	3186.3	2857.3	2529.7	2181.2	1811.7	1418.4	1004.4	569.3	113.1	-
11	1862.5	1609.0	1355.5	1082.9	791.0	477.0	144.1	-	-	-
12	497.4	479.6	461.9	443.5	425.2	406.0	387.5	368.7	349.9	331.9
13	33.2	29.1	25.1	21.0	[illegible].9	12.7	8.7	4.4	0.2	-
14	770.9	676.2	581.8	482.8	379.2	270.4	157.2	39.3	-	-
15	224.0	160.5	97.1	34.2	-	-	-	-	-	-
16	7.9	0.1	-	-	-	-	-	-	-	-
17	10.5	8.9	7.4	5.8	4.2	2.6	1.0	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	2860.2	2786.8	2714.0	2638.6	2560.5	2476.4	2390.1	2300.8	2208.8	2115.2
20	2001.0	1939.4	1877.8	1785.1	1653.2	1471.5	1229.8	915.1	513.1	6.5

are not very meaningful. The relative values are, however, useful in policy making. Referring again to the 1960 column of Table 9.1, we note that the value of the objective function would be reduced more if one additional dentist is trained than if one additional physician is trained. A Lagrange multiplier of zero for an occupation indicates that the supply constraint for that occupation was not binding for the period in question. Thus an additional person added to supply would not decrease the value of the objective function, as the health industry is already not using all available personnel.

The question of which constraints are slack is closely tied to the level of total resources assumed. The total resource constraint was binding in all periods in the application of the model discussed in Chapter 7. The researcher may well desire to rerun the program several times, using different levels of total resources. The solution obtained from any run of the recursive program represents an optimal solution only given the assumed level of resources available. A policy maker may well be interested in answers to questions of the form, "If we were to increase total expenditures on salaries for health personnel by a million dollars, where should we expend these funds?". If we assume nominal wage rates constant and consider only "small" increments to total expenditure, we can answer this question by analyzing the shadow prices. "Large" increments to total expenditure would require rerunning the program to optimize at the new level of total resources.

The same type of comment is applicable to the supply constraints for individual occupations. The policy maker may ask questions of the following nature. "Given that we train additional dentists as forecast, we will have a total supply in 1960 of 96,750 (Table 8.2). What will be the impact on

manpower requirements in other occupations if we set up a system of governmental scholarships designed to increase the supply of dentists by an additional 1,000 persons per year?" If total resources available for distribution as salaries remains unchanged, this increase in the supply of dentists will cause more dentists to be hired, in turn causing a decline in the employment of persons in other occupations. In order to ascertain the magnitude of this impact, it is necessary to rerun the model using the new supply constraint for dentists.

The model is well suited to interim revision of estimates based upon recent data. This may be done either annually, biannually, or as is convenient or necessary due to observed deviations from forecast magnitudes. The interim revision may amount to a full recomputation of all parameters, or one may modify the supply forecast only, the demand for services forecast only, or numerous other combinations. If demand coefficients or additions to supply, for example, are forecast in the form of functions of time, the interim revision can be handled by adding data for the most recent year to the base period time series and recomputing the regression based on a one-year longer base period, or by adding data for the most recent year and deleting the observation for the earliest year originally included. One may also note in the process of interim evaluation that the form of equation previously used to forecast some magnitude is no longer appropriate. Perhaps a nonlinear function should be substituted for a linear form, or perhaps some totally different independent variable should be used. Interim evaluation in a planning model can also serve to indicate the extent to which previous goals are being met, assuming that the supply forecast represents a desired rather than expected state.

Implications for Further Research

One of the most obvious implications for further work is to use the model to forecast for some period into the future, say 1970 or 1975. This type of forecast is useful primarily only for the numbers generated, however. Until such time as the results of the forecast can be compared against actual magnitudes, little additional information is made available regarding the accuracy or usefulness of the model. Some additional tests of the model which could be performed are discussed below.

We could convert the model into a nonrecursive form by simply making one supply forecast, namely for the target year. This has the disadvantage of obscuring the nature of the adjustment process and making sequential analysis difficult. If the supply forecast is generated for each year of the forecast period, the researcher can compare forecast supply with actual supply year by year. As long as these two magnitudes do not differ appreciably, there may be no reason to rerun the model to forecast for the target year on the basis of data available subsequent to the original forecast. The determination of this condition is not very easily made if supply is also forecast on a horizon basis.

This argument could be extended to apply to the demand side of the market. That is, instead of forecasting demand only for the target year, we could forecast demand for each year of the forecast period. This would result in the use of an objective function of the form $\Sigma_j [r_j (x^*_{jt} - x_{jt})/x^*_{jt}]^2$. This would make the model more of a simulation type model and less of a planning type model. The method has some appeal, because there are no specific future data that the health industry is, in fact, using as a horizon for planning. The census years are natural selections for forecast dates only because of the nature of much of the data available. The testing of the

model using annual demand forecasts is suggested as one implication for further research. I hypothesize that the model using yearly forecasts of demand would not yield forecasts which are as accurate as those obtained using the time horizon demand concept. This is because errors would tend to cumulate unless some provision were made to allow unutilized supply in one period to reenter the model at some later point in time. The model as currently formulated has upper bound constraints on supply of the form $x_{jt} \leq (1 + B_{jMax,t}) x_{j,t-1}$. If a forecast of demand for any period is too low, such that some portion of supply was erroneously not utilized by the model, this portion of supply would not be available in later periods even if excess demand in some later period is positive. This problem, if it turned out to be a problem, could be handled by allowing for some sort of "carry-over" of unutilized personnel from one period to the next. In general, to make annual demand forecasts useful more and better data are needed than would be true of the horizon type of demand forecasts.

Another interesting application of the model would be to use some variation of it to study the requirements for physicians, categorized by field of specialty. There are considerable data available regarding trends in physician specialties (111, pp. 21-29 and 78, pp. 160-72). Several new problems would arise in this formulation. Service categories would have to be redefined. The concept of supply would become troublesome, as many physicians are specialists in more than one field. Specialists can always perform the duties of general practitioners if a surplus of specialists in some field should develop. The total resource constraint would also require respecification.

The model, or some variation of it, could also be adapted for use in some sub-national area such as a state or group of states. The parameters

would, of course, have to be reestimated, but the primary change necessary in the model relates to the consideration of migration of personnel. For some occupations, good information is available regarding geographical mobility. Information is available, for example, on the state of practice of dentists classified by dental school and year of graduation (112, pp. 117-50). For most occupations, however, this type of information is not available, and it may be necessary to gather survey data in order to forecast migration. Most of the necessary data will be more difficult to gather for a sub-national area as published sources usually provide no regional breakdown.

The model may also be applicable to industries other than health, particularly industries in which the individual entities, or "firms," cannot reasonably be expected to operate on the profit maximization principle. Education may be an activity which could be analyzed using the model developed herein. Decision making in education, even more than in health, is done by public agencies. The concept of manpower planning is therefore more realistic in education than in manufacturing, for example. The demand for educational services could be expressed in terms of numbers of pupils in an age category. Very good forecasts of these magnitudes could be obtained by using census data on population. The model would be most appropriate as a macroeconomic model applied to the nation as a whole. For very small units, such as an individual school district, another type of objective function might be more appropriate. Some type of constrained cost minimization, for example, might be more meaningful.

The model could be expanded into a two-way recursive system, as previously noted. An explicit feedback loop could be incorporated whereby future supply is affected by the magnitude of current excess demand. It is

possible, but not necessary, that this can be accomplished by using wage rates as a variable. If excess demand is "large," or alternatively if it increases, we could cause the model to predict an increase in wage rates. This increase in wages in turn elicits an increase in supply. The specification of the speed of adjustment factors, which state how much wages rise due to a given change in excess demand and how much and how rapidly supply changes in response to a given change in wage rates, is very difficult operationally. A model such as this would be more attractive theoretically but might be less accurate as a forecasting model. Yet, I believe the development of such a model would be of interest purely as a simulation attempt. Care would have to be exercised in the selection of included occupations as the data requirements are very stringent. One could bypass the wage changes and estimate a supply response to excess demand conditions directly. The estimation of the speed of adjustment factor is still a problem.

These examples illustrate some ideas for further research which have occurred to me in the process of performing this study. It may be noted that many of these variations of the model are designed to answer questions other than the problem of interest in the bulk of this study, namely the forecasting of manpower requirements in the health occupations on a national scale. Given the state of data availability existing, I believe that the recursive programming model previously presented is the most useful of the alternatives I have considered for analyzing the problem to which this study has been addressed.

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